Comparison of wind trends from MERRA-2 data and a multisource wind index (23 regions in Europe)

Why does the choice of the reference sources matter so much?

Marion Jude
Eoltech, 8 rue du Colonel Driant, 31400 Toulouse, France
marion.jude@eoltech.fr, Tel : +33 5 61 15 44 13

PO.015 WindEurope 2018 Conference at the Global Wind Summit, Hamburg, September 2018

Abstract

The long term prediction of wind resource is one of the key issues of energy yield assessments, and often explains the main deviations between several studies for a given project. In order to assess to what extent the choice of the long term reference sources can lead to deviations in terms of estimated long term production, a comparative analysis was carried out between wind speed trends obtained via MERRA-2 data on the one hand and a multisource index based on ground measurements on the other hand for 23 regions in 6 European countries.

The multisource index is considered as the reference as it results from the combination of wind measurements from meteorological stations rigorously selected to be coherent between each other and consistent over the long term period considered (cross-checking of convergent and independent information).

The comparison was carried out for the period 2000-2017 (18 years) over 23 areas in Europe: 8 in France, 5 in Germany, 5 in the United Kingdom, 3 in Denmark, 1 in the Netherlands and 1 in Belgium.

These analyses have shown different conclusions from one area to another. In most regions the long term trends proposed by MERRA-2 data are very similar to the reference one. Some punctual differences can lead to significant deviations in terms of long term prediction, but they are limited to several specific years. However, in several regions, a significant deviation in the long term trend proposed by MERRA-2 data has been observed.

1 Introduction

The long term prediction is a key issue in the context of the wind potential assessment of a wind farm under development. Prior to the choice of the methodology to be considered, the question arises of selecting relevant long term wind data as a reference. The aim of this study was to compare the long term trends proposed by ground meteorological station whose consistency over time has been ensured by a rigorous coherence analysis, and the trends proposed by MERRA-2 wind data over several areas in North-western Europe.

2 Methods

Several areas, considered homogeneous in terms of evolution of wind speed and wind roses, were identified in North-western Europe.

Within each area, a regional multisource wind index was established based on the combination of data measured by at least 3 ground meteorological stations. These stations were carefully selected in order to provide a reliable and consistent wind trend over time. Thus, within each region, all selected sources are totally independent from one another and provide convergent results in terms of annual windiness (criteria on the dispersion of the standardized annual wind speeds).

A total of 23 areas was retained for the analysis as shown on Figure 1. On this map, the ground meteorological stations are represented with blue icons and MERRA-2 simulations with pink icons.

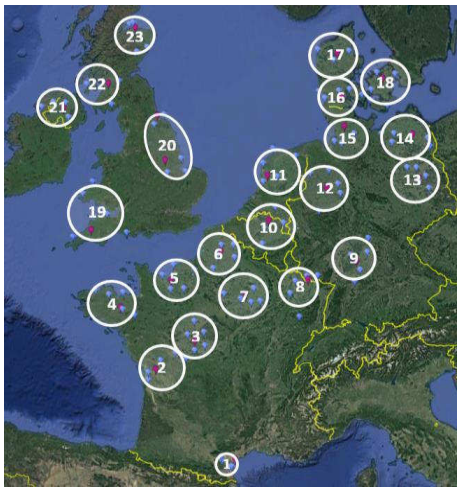

Figure 1: Location of the 23 regions considered for the analysis

The evolution of the annual standardized wind speeds obtained from measured wind data and from MERRA-2 data were compared within each region, as shown in both examples displayed in Figures 2 and 3 (Region 4 Brittany in France and Region 10 Belgium).

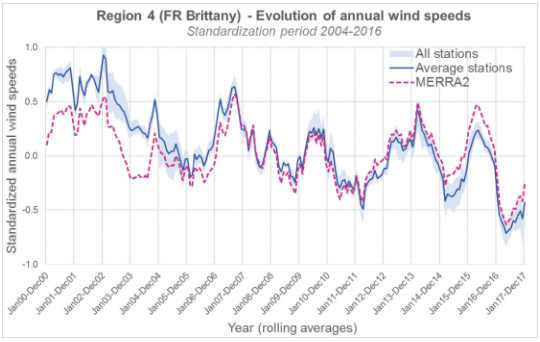

Figure 2 : Evolution of standardized annual wind speeds Brittany (Ground wind measurements and MERRA-2)

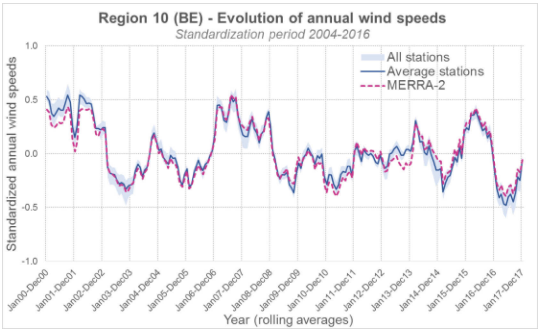

Figure 3 : Evolution of standardized annual wind speeds Belgium (Ground wind measurements and MERRA-2)

Thus, in each of the 23 regions, the multisource index resulting from the combination of the selected stations was compared to the wind index issued from MERRA-2 data.

Note that, in the frame of this analysis, the multisource index is considered as the reference. The convergent conclusions that can be made from these independent sources over time ensure the reliability and the time consistency of this index. Indeed, each source taken separately would provide similar conclusions than the others in terms of representativeness of the wind resource.

The other index, called MERRA-2 index, corresponds to a MERRA-2 dataset simulated in the area. It should be noted that using a combination of several adjacent MERRA-2 simulations would not actually be considered as a multisource index in the sense that the MERRA-2 datasets at different locations are not fully independent from one another.

The comparison of long term trends provided by both wind indexes in each area was carried out and main results are presented in the following sections.

3 Results

3.1 Main outcomes

Deviations between both wind indexes (Multisource referent and MERRA-2) were analysed for each region and has led to gather regions with similar global outcomes into two groups A and B.

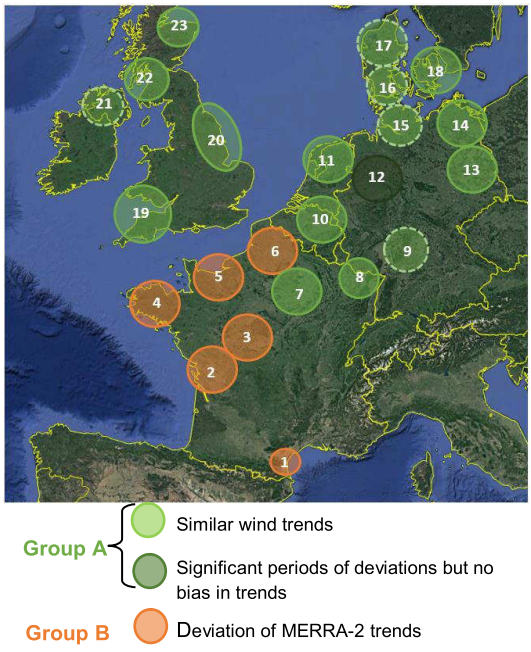

Figure 4: Breakdown of regions in group A and B

In some regions (9, 15, 16, 17 and 21, circled in dotted green on the map) it was not possible to establish a multisource index back to 2000 (doubts about consistency of wind measurements that far). Comparisons were carried out since 2001 and 2002 in these areas.

Group	Key findings
A	**Similar wind trends** (Index multisource – Index MERRA-2) stable since 2000 **Region 12** : significant periods of deviations, but no gradual bias (see. annual analysis)
B	**Deviation of MERRA-2 wind trend** (Index multisource – Index MERRA-2) decreases over time

Table 1 : Aggregation of regions with similar outcomes

3.2 Analysis of long term trends: evolution of 10-year wind speeds since 2000

Figures below present the evolution of 10-year wind indexes issued from both sources (referent multisource index Figure 5 and MERRA-2 wind index Figure 6). For each region, wind speed indexes are calculated using the decade 2008-2017 as reference (100% corresponds to the average wind speed of the considered region over the last decade).

For instance in region 4 (Brittany, part of group B), the average wind speed observed from ground measurements on the decade 2000-2009 is about 8 % higher than the average wind speed recorded on the decade 2008-2017 (multisource index = 108% see figure 5).

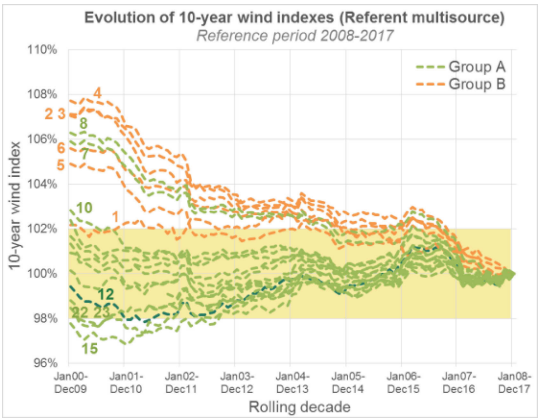

Figure 5 : Evolution of 10-year wind indexes per region (Multisource wind index)

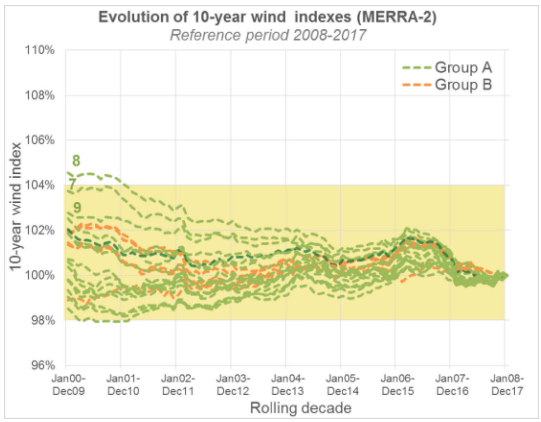

Figure 6: Evolution of 10-year wind indexes per region (MERRA-2 wind index)

Thus, whereas the multisource wind index shows a significant downward trend for regions 2 to 6 (North-western France), with -5 % to -8 % on the 10-year wind speed, MERRA-2 wind data do not show any remarkable trend.

Both indexes show a decreasing decadal wind speed for regions 7 and 8 (North-eastern France), although the wind speed deficit proposed by MERRA-2 index is slightly lower.

In order to better appreciate the discrepancies between both sources of data, deviations between both 10-year wind speed indexes are presented in Figure 7.

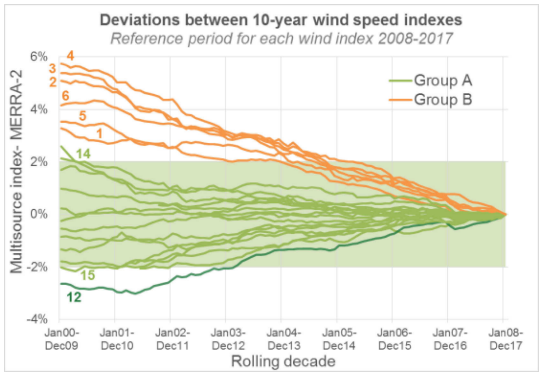

Figure 7: (10-year multisource index)–(10-year MERRA-2 index) Reference period for each wind speed index 2008-2017

Hence, significant deviations between both indexes are found for regions 1 to 6 in France, where the decreasing wind trends observed on ground measurements are not showed by MERRA-2 wind data.

A noticeable deviation is also seen for region 12 (slight increase of the trends observed on wind measurements whereas MERRA-2 data show a slight decrease).

Figure 8 displays the deviations of annual wind speed indexes from both sources for region 1 to 6 and for region 12, in order to analyse the evolution of the deviation on a finer time scale. From this figure, we can observe that the deviation between both indexes is gradual for regions 1 to 6 (group B), whereas for region 12 a stable discrepancy can be observed between 2001 and 2009.

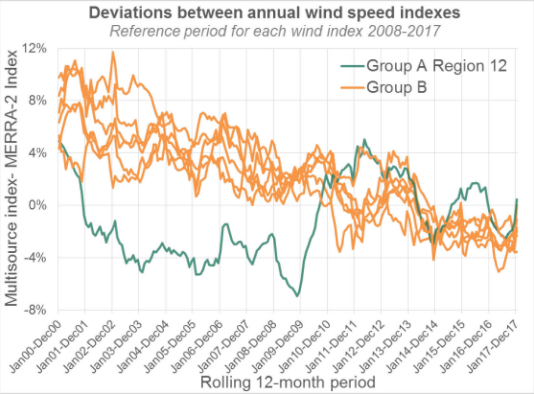

Figure 8: (Annual multisource index)–(Annual MERRA-2 index) Reference period for each wind speed index 2008-2017

Thus, for regions 7 to 23 (gathered in **group A**), similar wind trends have been observed between MERRA-2 data and the multisource index issued from ground measurements (deviations on 10-year wind speed indexes < ± 2 %), except for region 12 where a discrepancy was observed between 2001 and 2009.

By contrast, in most of the French studied areas gathered in **Goup B** (mainly located in the Northwest of the country), significant decreasing trends have been observed from wind measurements (steady wind speed deficit over years) whereas MERRA-2 data do not show any trend.

It should be noted that the decreasing trend observed for regions 7 and 8 in the Northeast of France is also observed with MERRA-2 data.

3.3 Annual discrepancies between both indexes

Annual discrepancies between both wind indexes were determined for each region from all the 12-month cycles since 2000, using the decade 2008-2017 as reference for each index (i.e. for each index 100% corresponds to the average wind speed over the decade 2008-2017).

The following table presents minimum, first decile, median, ninth decile and maximum of the discrepancies between both indexes for each region. This analysis allows to quantify the deviations which could result on the estimation of long term wind speed in the framework of an energy yield assessment.

Distribution of discrepancies on annual wind indexes per region (2000-2017)						
Gr.	Reg.	Min	D1	Med	D9	Max
B	1	-4.1%	-2.1%	2.0%	4.5%	5.8%
	2	-3.5%	-2.5%	2.8%	6.8%	10.6%
	3	-5.1%	-2.5%	2.8%	7.7%	11.1%
	4	-3.6%	-2.7%	2.3%	9.4%	11.7%
	5	-3.4%	-2.3%	1.7%	5.1%	7.9%
	6	-2.8%	-1.7%	2.3%	6.0%	7.8%
A	7	-4.1%	-1.4%	0.9%	3.3%	8.7%
	8	-2.8%	-1.6%	0.7%	3.1%	7.4%
	9	-6.1%	-4.2%	-0.6%	3.0%	4.3%
	10	-3.1%	-1.6%	0.4%	2.4%	4.0%
	11	-3.3%	-1.8%	-0.5%	0.6%	1.9%
	12	-7.0%	-4.5%	-2.0%	3.0%	5.0%
	13	-2.3%	-1.8%	-0.3%	1.2%	2.1%
	14	-3.1%	-2.0%	0.4%	4.8%	10.6%
	15	-5.2%	-3.6%	-0.9%	1.6%	3.2%
	16	-3.7%	-1.8%	0.2%	1.8%	3.2%
	17	-1.9%	-1.3%	-0.1%	1.4%	2.3%
	18	-2.2%	-1.3%	0.0%	1.3%	2.3%
	19	-3.4%	-1.6%	0.0%	1.8%	3.0%
	20	-2.7%	-1.4%	0.1%	1.4%	2.4%
	21	-5.6%	-3.7%	-0.8%	2.3%	4.4%
	22	-4.6%	-3.0%	-1.2%	1.9%	3.9%
	23	-6.3%	-2.9%	-0.7%	1.6%	3.4%

Table 2: Comparison of wind resource between long term periods – Referent multisource vs MERRA-2

Beyond deviations due to the bias in the long term trends observed for group B regions 1 to 6 highlighted in orange), the results show that the use of MERRA-2 data for the windiness analysis of a 12-month period can lead to significant deviations compared to the multisource index.

If we take this example of regions from Group A, the extreme deviations of annual indexes (Min and Max in table 2) generally exceed ±2 % for all regions, and even exceed ±4 % in several cases.

If we consider the proportion of values outside D1 and D9 (i.e. 1/5 of the years considered), the deviations exceed ± 1.5 % for most regions, which would lead to

significant biases in terms of long term prediction (> 3 % on production).

The regions with fewer deviations between both indexes are regions 16 to 20 in Denmark and in England, where deviations on wind speed indexes are below ± 2 % for 4/5 of the years (i.e. inside D1 and D9).

4 Considerations on longer periods

The previous results could give the appearance that the deviation between both sources of data (ground measurements and MERRA-2) is specific to France. Nevertheless, wind trends were compared going back in time further in some regions and deviations in long term trends were observed also in Germany, Belgium and the Netherlands, where a decreasing trend could be observed from ground measurements before 2000.

Several regions where the comparison were made over the past 35 years are presented on the map below. It should be noted that regions 15 and 16 were gathered as they present similar trends, in order to dispose of sufficient consistent data that far.

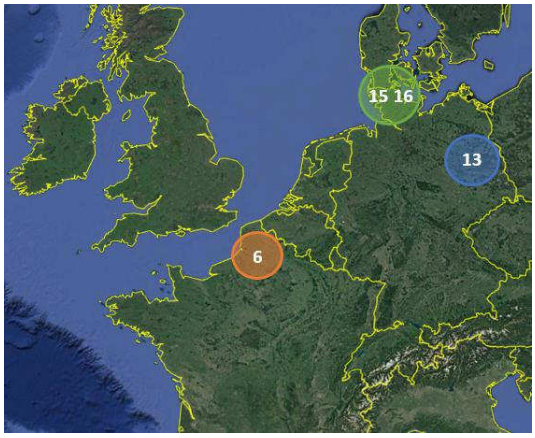

Figure 9: Areas where the comparison between both indexes could be made back to 1980

Figure 10 presents the evolution of the 10-year wind speeds issued from both sources since 1980.

Thus, the deviations highlighted on MERRA-2 long term trends are not specific to France. Indeed, they seem to appear as soon as a trend (upward or downward) is highlighted from the analysis of ground measurements.

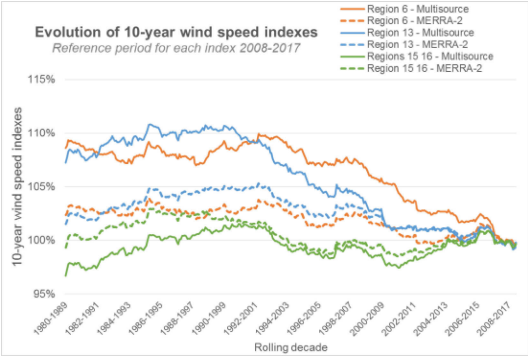

Figure 10: Evolution of the 10-year wind speeds since 1980 (Multisource and MERRA-2 indexes)

As a reminder, the time-consistency of the referent indexes issued from ground measurements has been ensured in order to avoid a possible bias due to the evolution of the roughness or measuring conditions.

5 Conclusions

In regions where significant decreasing wind trends were highlighted by the referent multisource wind index, MERRA-2 trends remain relatively stable. Due to this deviation, the choice of the sources considered for long term prediction will impact significantly the estimation of long term production. In such areas, the choice of the reference sources is all the more so important as the long term reference period is long : if using 10 years will globally lead to similar results, significant deviations will appear while using 15 or 20 years.

In regions where the long term trends between the multisource index and MERRA-2 are similar, using either of both sources would lead to similar conclusions for the long term prediction in most cases. Nevertheless, punctual deviations were observed on several years which might lead to significant biases for the estimation of the long term wind speed of a project (random bias).

Therefore, even if re-analysis data are useful in the wind industry, when it is possible, their use for long term prediction should be cross-checked with independent ground measurements and sometimes questionned in order to limit the uncertainty on the long term prediction process.

The cause of the deviations between wind trends observed from measurements and the ones issued from re-analysis data is unclear at this stage, but will be the topic of further work.