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Does background noise vary with seasons ?

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1. Introduction

Regarding wind turbine noise, compliance with French regulations depends in part on the background noise. One of the main criterion is indeed an emergence descriptor, which is the difference between the levels of total noise and background noise. Basically, if the total noise level exceeds 35 dB(A), the emergence must remain below a threshold of 5 dB(A) during the day and 3 dB(A) at night. Acoustic measurement campaigns are generally of one to two weeks duration, which makes it difficult to assess the seasonal variation of background noise. However, although their influence on noise levels is not well known, the fact remains that anthropogenic, floristic and faunistic activities do vary throughout the year. Besides, as for most wind farms, the acoustic compliance requires noise curtailments that are often based on a most constraining scenario, it is also of interest to assess the proportion of production losses that could be avoided by a seasonal refinement of the noise curtailment plans.
This study focuses on the particular case of a village in northern France where a long-term measurement campaign has been carried out. Acoustic measurements in two locations were conducted from late January to August 2014 alongside meteorological measurements. The

data were processed over a 2-week moving window in accordance with the best practices of the French profession, as described by the draft standard NFS 31-114. Then, considering the evolution of the background noise level obtained, an assessment of the potential earnings were carried out for typical wind farm layouts.

2. A quick reminder of French regulations regarding wind turbine noise

Depending on the country, both thresholds and indicators vary, making comparisons between regulations difficult. For example, Germany uses the LAeq indicator and England the LA90, with accordingly adjusted thresholds.
This study is based on French practices and French regulation.

2.1 French legislation on classified installations

In France, since the publication of the decree of August 26, 2011, wind farms enter the scope of classified installations for environmental protection (installation classée pour la protection de l'environnement) (ICPE) regime. They are subject to authorization. As such, there are three acoustic criteria to be respected to prevent neighboring areas from noise :

- Compliance with global emergence values in dB(A);
- Compliance with maximum ambient noise values in dB(A);
- Tonal noise absence.

Concerning the respect of global emergence values, the regulatory thresholds are of +5 dB(A) on day time (7am-10pm) and +3 dB(A) at night (10pm-7am). If the total noise level is less than 35 dB(A), these constraints no longer apply. The areas concerned include the indoor and outdoor living areas and the constructible areas defined in the current urban planning document.

Table 1 : Global emergence thresholds

Total noise level	Permissible maximum emergence	
	Day (7am-10pm)	Night (10pm-7am)
Lamb > 35 dBA	5 dB(A)	3 dB(A)

The maximum noise criterion is the adaptation to onshore wind power of a pre-existing standard that was intended for industrial installations. The smallest polygon embracing a buffer zone of 1.2 times the total height of the wind turbines symbolizes the property limit of the park, where the maximum noise criterion applies. The thresholds are 70 dB(A) on day time (7am-10pm) and 60 dB(A) night time. These rules do not apply if the background noise level is higher than the regulatory limit (70 or 60 dB(A)).

Finally, the tonal noise criterion concerns any peak in the wind turbine's emission spectrum. In regulatory terms, this criterion results in a maximum emergence not to be exceeded between each third octave band of the spectrum and the four adjacent bands (the two immediately lower bands and the two immediately upper bands). The limits to be observed are 10 dB for third octave bands centered from 50 to 315 Hz and 5 dB for third octave bands centered from 400 to 8000 Hz. This analysis should be conducted in residential areas, considering the spectrum of noise attributable to wind turbines. Frequency peak apparition as defined before shall not exceed 30% duration time.

2.2 Noise measurement standards

The draft standard NFS 31-114 is used by acoustics professionals to process wind energy measurements in France, in accordance with the decree of August 26, 2011.
Measurement campaigns generally last between 10 and 30 days. The measurement points must be carefully chosen in order to check the compliance of the wind farm with the most

exposed residents., The receivers must be installed in an ordinary acoustic environment of a living space.
Measurements are made with an integrating sound level meter or a class 1 measuring system (according to NF EN 60804 or NF EN 61672-1). The devices shall measure Leq every second. Sound level meters are placed at least 2m from the facades of the houses.

The standard recommends an analysis of noise levels as a function of wind speed. In addition to the distinction between day and night periods, it is advisable to work on homogeneous classes in wind direction, road traffic intensity, season, etc. Thus, within a homogeneous class, the only parameter influencing the noise level shall be the wind speed. The descriptor used by the standard is the median level L5010min based on measured Leq, 1s and each bin must contain at least 10 samples. Once the distribution of samples has been made, medians that are centered on integer wind speed values are extracted from the scatter plots. The centered medians characterize the measured noise levels.

3. A review of the method used for the measurement analysis NFS31-114

This study focuses on the particular case of a village in northern France where a long-term measurement campaign has been carried out. Acoustic measurements in two locations were conducted from late January to August 2014 alongside meteorological measurements. The data were processed over a 2-week moving window in accordance with the best practices of the French profession, as described by the draft standard NFS 31-114.

3.1 Experimental set-up

Acoustic measurement took place in two locations R1 and R2 close to each other in Pas-de-Calais, France. The devices measured from 01/23/2014 to 08/21/2014, i.e. 210 days. Recovery rates were 70% for R1 and 87% for R2. Figure 1 shows photographs of the measurement points taken in winter and summer. Several indicators were measured on a second scale, including global LA_{eq} and LZ_{eq} per third octave band.

Figure 1 : Pictures of the acoustic measurement points

The meteorological data were taken from a wind farm located approximately 4 km from the acoustic measurement points. The nearest wind turbine is 2.8 km away from R1, so it can be

assumed that the wind farm acoustic contribution is negligible. However, since the site roughness is homogeneous between the windfarm and the receivers, SCADA data from this power plant provide a good correlation with noise levels. Figure 2 allows to locate the different measurement sites.
SCADA data give for each wind turbine the average of the wind direction, wind speed and active power achieved on a 10-minute basis. Since the wind direction and wind speed data are very close from one wind turbine to another, the following analysis gives very similar results depending on the wind data source chosen.

Figure 2 : Location of the instruments

3.2 Data processing

First, acoustic data were aggregated to $LA50_{10min}$ according to French standard Pr-NFS 31-114 and synced with SCADA data.
The evolution of acoustic data according to the hours of the day led to the consideration of three distinct periods: day (7am-8pm), evening (8pm-11pm), night (11pm-7am). As for wind direction, it had no significant influence on sound levels. In addition, the main wind regime, from the south-western sector, was overwhelmingly represented (see Appendix 0 Wind rose from 2014/01/24 to 2014/08/21).
As some noise and wind speed pairs did not follow an increasing trend in noise level with wind speed, they were removed from the analyses. These samples are considered as disturbed because they are very high compared to representative values. For instance, dawn chorus needed special care and treatment because it is not representative of the daytime period. An overview of the data once filtered is available in Appendix 0 Data filtering.

After having been properly prepared, data have been processed over a 2-week moving window, following the same standard Pr-NFS 31-114. In the case of a too great lack of availability, that is, if the available data represent less than 10 cumulative days out of the expected 15 days, the statistics have not been calculated.

Beside the calculation of the recentered medians, the following values have been determined for each wind speed bin : the most frequent direction based on Kernel density estimation, median active power and uncertainty of the background noise level indicator.
In parallel with these analysis over reduced periods, an estimation of long-term background sound levels was carried out, allowing the seasonal variation around the median value to be calculated. This last processing step allows to free the operator from other parameters such as wind speed and focus only on the influence of the time of year.

4. Results of a 7-month acoustic measurement campaign

This section describes the results of the experiment of measuring background noise for several months at the same locations. Details concerning data processing can be found in the previous section.

4.1 Long-term background noise levels

Figure 3 shows long-term background noise levels calculated over the entire period of measurement, from 2014/01/24 to 2014/08/21. On the same subgraph, the difference between the curves comes from the wind speed data source : wind turbine E1, E2, E3 or E4. It appears that daytime and nighttime values are more reliable than evening period values, especially for low wind speed. This is due to the fact that the evening period is a transitional period where both night and daytime noise levels are present. In addition, there are fewer samples for this period because the time frame covered is smaller. It can therefore be seen that the study of the seasonal variability of evening noise levels will be constrained by the dispersion of the data.

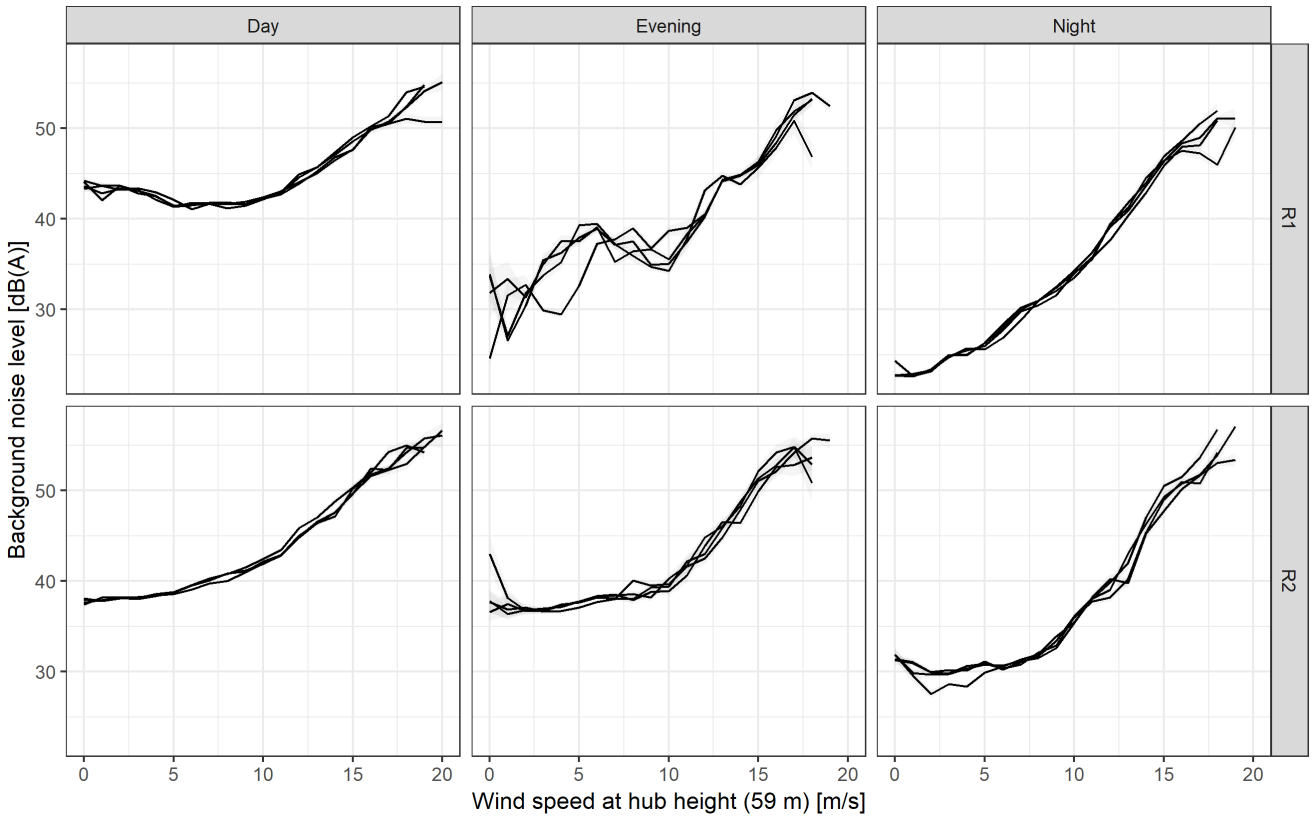

Figure 3 : Long-term background noise levels

4.2 Background noise variability

Figure 4 shows for wind speed bins from 1 to 15 m/s the background noise level variability around its long-term value. Red areas correspond to relatively louder situations, blue areas correspond to quieter situations.

The results show that background noise can vary with a 2 dB(A) amplitude around its median value because of seasonality. Both locations recorded a general increase of night-time noise levels during spring. It has to be noted that noise levels at low wind speed are more influenced by seasons than noise levels at high wind speed.

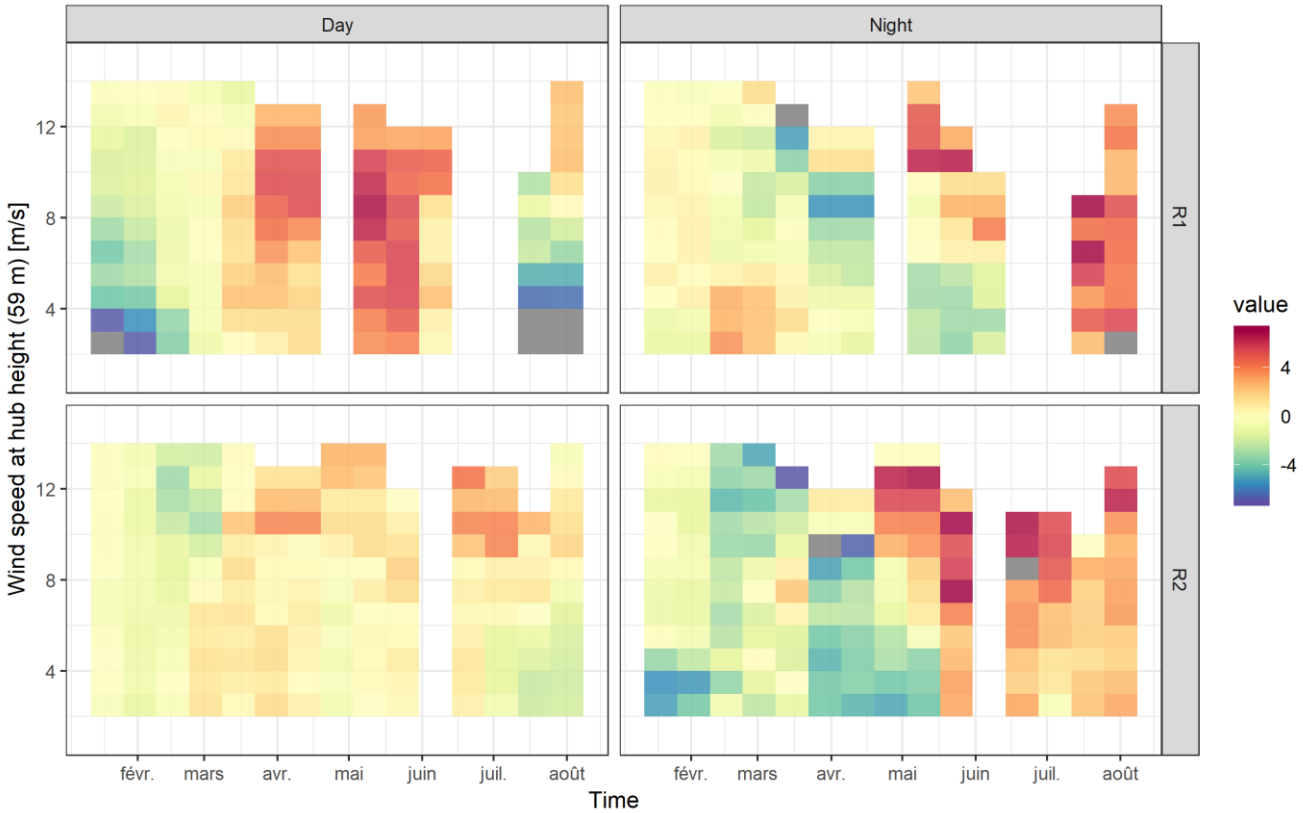

Figure 4 : Heat map of background noise variability regarding time period, with respect to wind speed

It has been noted that noise levels at low wind speed are more influenced by seasons than noise levels at high wind speed. However, to give a general order of magnitude of the variability of background noise level over the year, regardless of wind speed, averages of the variability weighted by the inverse of the uncertainty of the bins were plotted on Figure 5. Variability is significative and confirm a general increase during spring.

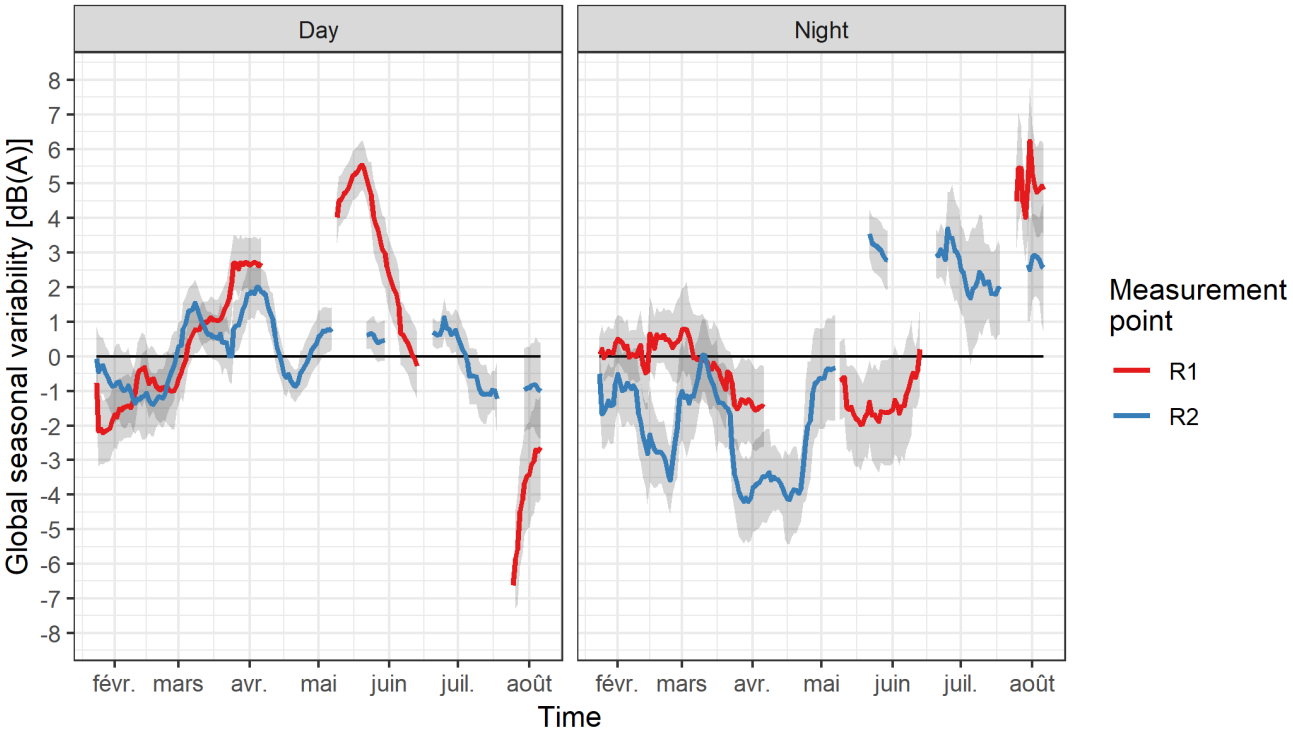

Figure 5 : Global seasonal variability

5. Presentation of the use case

5.1 Use case layout

A typical French onshore wind farm layout was considered as a use case. In this example, 4 wind turbines ENERCON E-103 EP2 with serrated trailing edge (STE) are surrounded by 8 receivers placed at the nearest houses. The minimal distance between wind turbines and receivers is 620 m.
The wind turbine model considered features 6 noise operating modes in addition with standard mode and stop mode.

5.2 Background noise hypothesis

Measurements lasted from January to August and there were gaps in the data. To work on a use case that would consider the year as a whole, the missing noise levels were roughly estimated using a random forest algorithm. It was assumed that there was a symmetrical behavior around the summer period. Despite the confidence that can be placed in this assumption, caution should be maintained with respect to the results for the September to December period because background noise levels have not been measured.

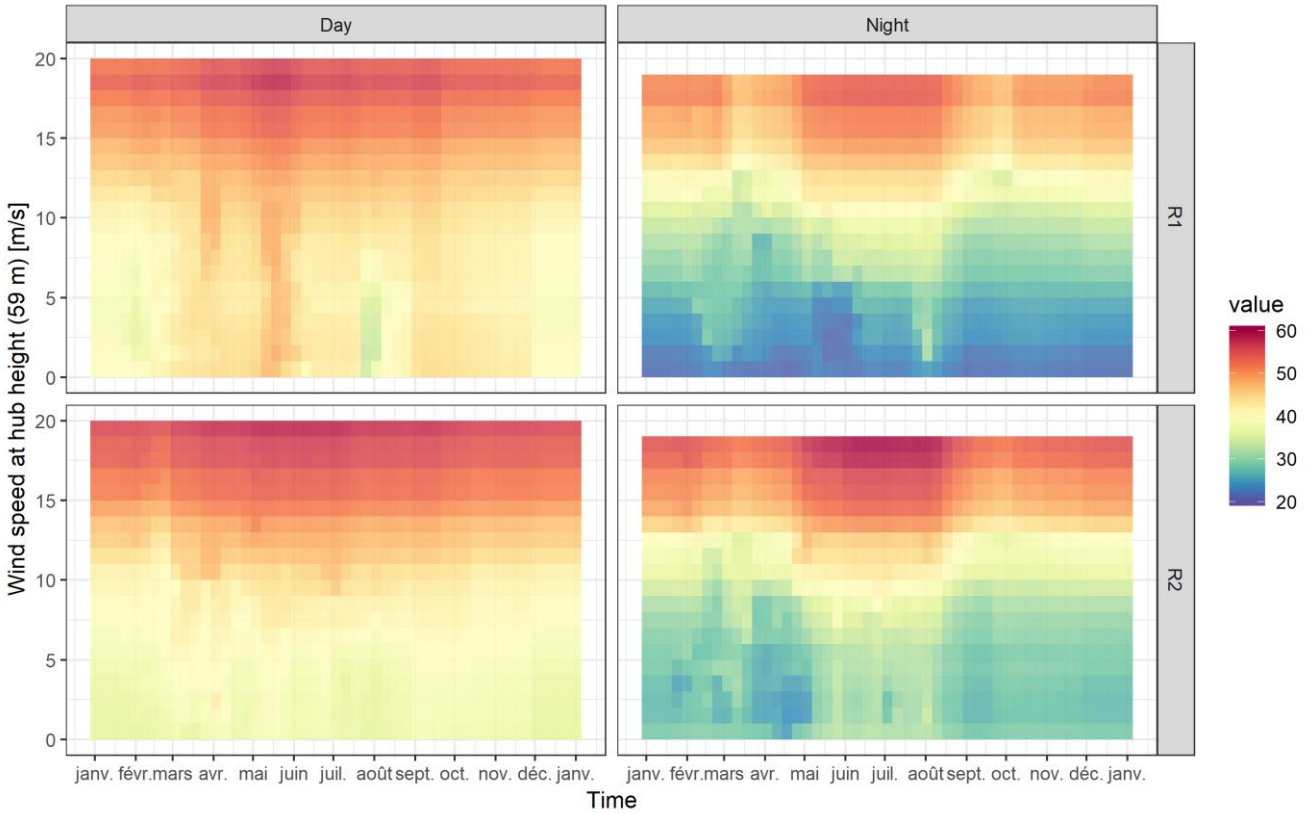

Figure 6 : Rough estimate of background noise levels throughout the year

Figure 6 illustrates the levels selected for the subsequent analysis.

The assignment of the noise levels R1 and R2 was made arbitrarily. Basically, R1 background noise curves were assigned to even receivers R'2, R'4, R'6 and R'8 and R2 curves were assigned to odd receivers R'1, R'3, R'7 and R'9.

6. Influence of seasonality on acoustic curtailment losses

6.1 Acoustic impact in standard operation

From the annual variations in background noise, it is possible to determine what conclusions would have been reached by acoustic studies whose measurement campaigns would have been carried out at different times. Figure 7 illustrates the evolution throughout the year of the acoustic impact of the wind farm under standard operating conditions. The impact is quantified by the number of non-compliances with regulatory thresholds and by the maximum acoustic exceedance.

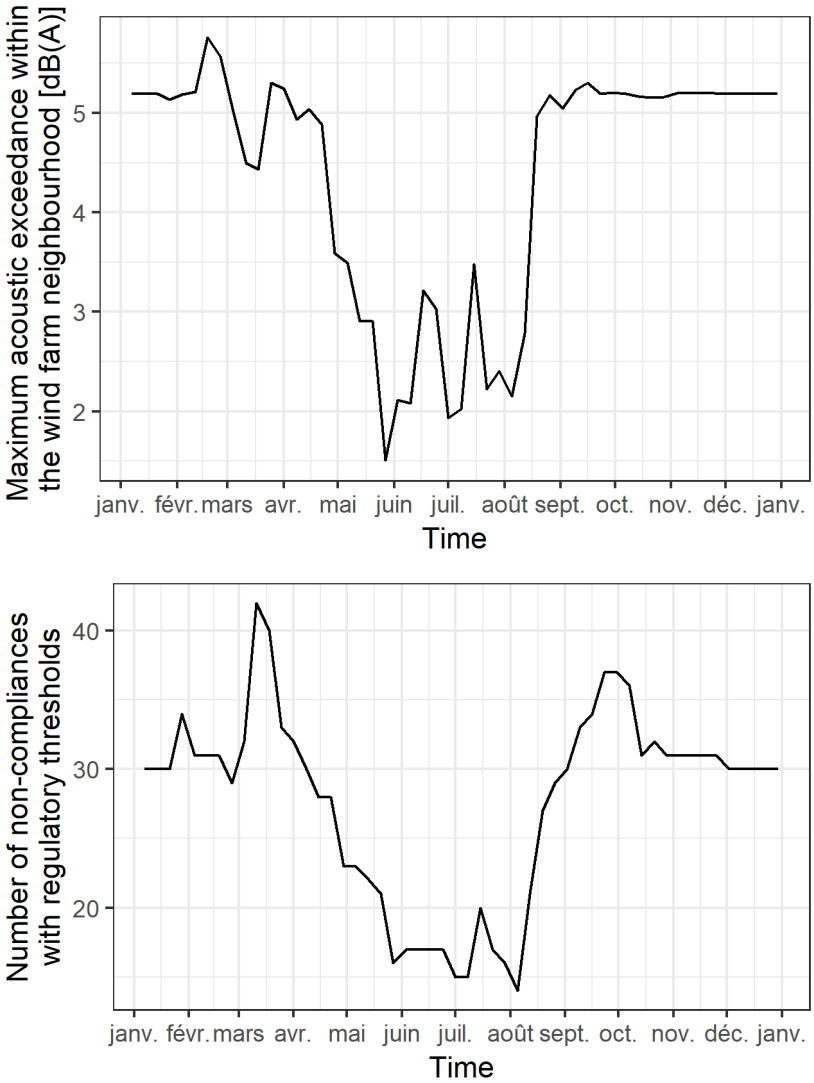

Figure 7 : Acoustic impact of the wind farm

Obviously, the impact is higher in winter than in summer because background noise levels are lower. On this particular use case, maximum exceedance vary between 2 dB(A) in summer and 5 dB(A) in winter. An acoustic curtailment plan is therefore necessary whatever the time of year considered for acoustic measurements. However, since the constraint is less severe in the summer, it is expected that the associated losses will be lower.
Nighttime background noise levels fluctuations have a major influence on the acoustic impact because night is the period of highest risk. Indeed, regulatory threshold is 3 dB(A) and background noise are lower than during the day.

6.2 Long-term production losses due to acoustic curtailments

When a wind farm in standard operation does not comply with acoustic requirements, a curtailment plan is disigned in order to sufficiently reduce its acoustic impact, without unnecessarily reducing production. Figure 8 represents the evolution of acoustic losses that could be expected if background noise levels measured during a given 15-days window were used to establish a yearly acoustic curtailment plan on this particular wind farm.

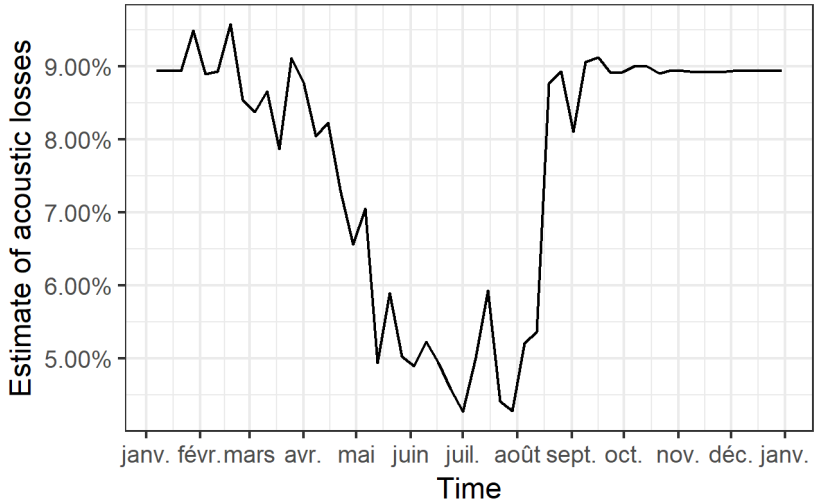

Figure 8 : Production losses due to acoustic curtailments

Long-term production losses, expressed in percent of the wind farm gross production, vary from 5% in summer and 9% during winter.

The results are heavily dependent on the assumptions regarding the wind farm layout and the turbine specifications. Therefore, production losses could be way more or less sensitive to background noise variations.
Further investigations should look at the actual acoustic impact of a wind farm under a given curtailment plan. Also, an estimate of the production gains and acoustic confort provided by a dynamic curtailment plan would be a great contribution.

7. Conclusions

The results show that background noise can vary with a 2 dB(A) amplitude around its median value because of seasonality. Both locations recorded a general increase of night-time noise levels during spring. This could have an outcome of several percent on wind farms Annual Energy Production (AEP).

References

AFNOR (2011) *Projet NF S 31-114 Mesurage du bruit dans l'environnement avec et sans activité éolienne*
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Commission Electrotechnique Internationale (2005). *Cei 61400-12-1 :2005. AFNOR*.

Appendices

Wind rose from 2014/01/24 to 2014/08/21

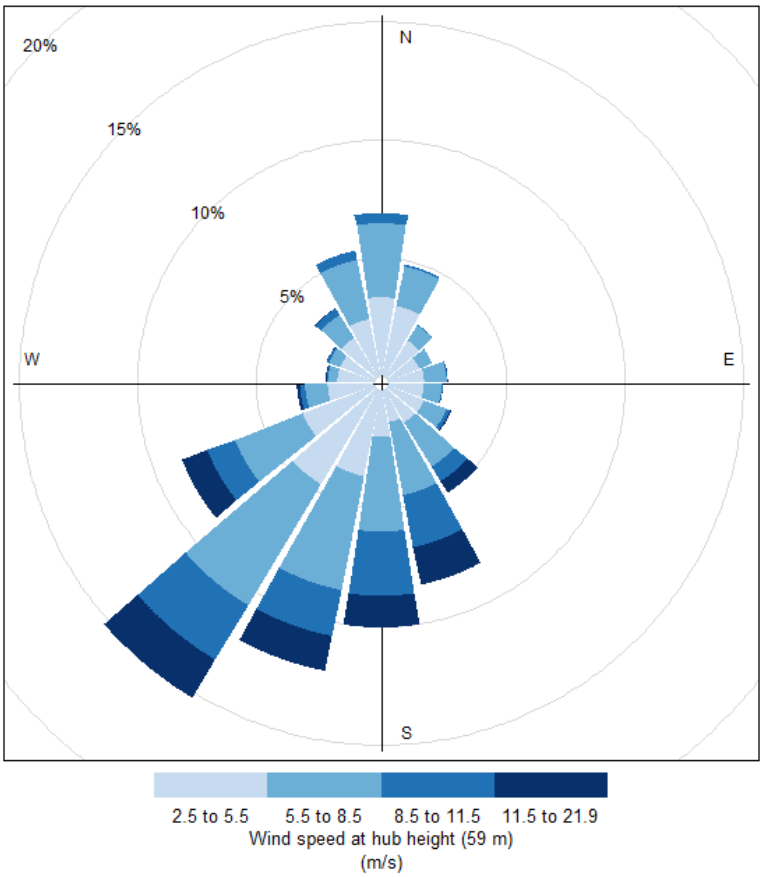

Figure 9 : Wind rose from 2014/01/24 to 2014/08/21

Data filtering - Location R1

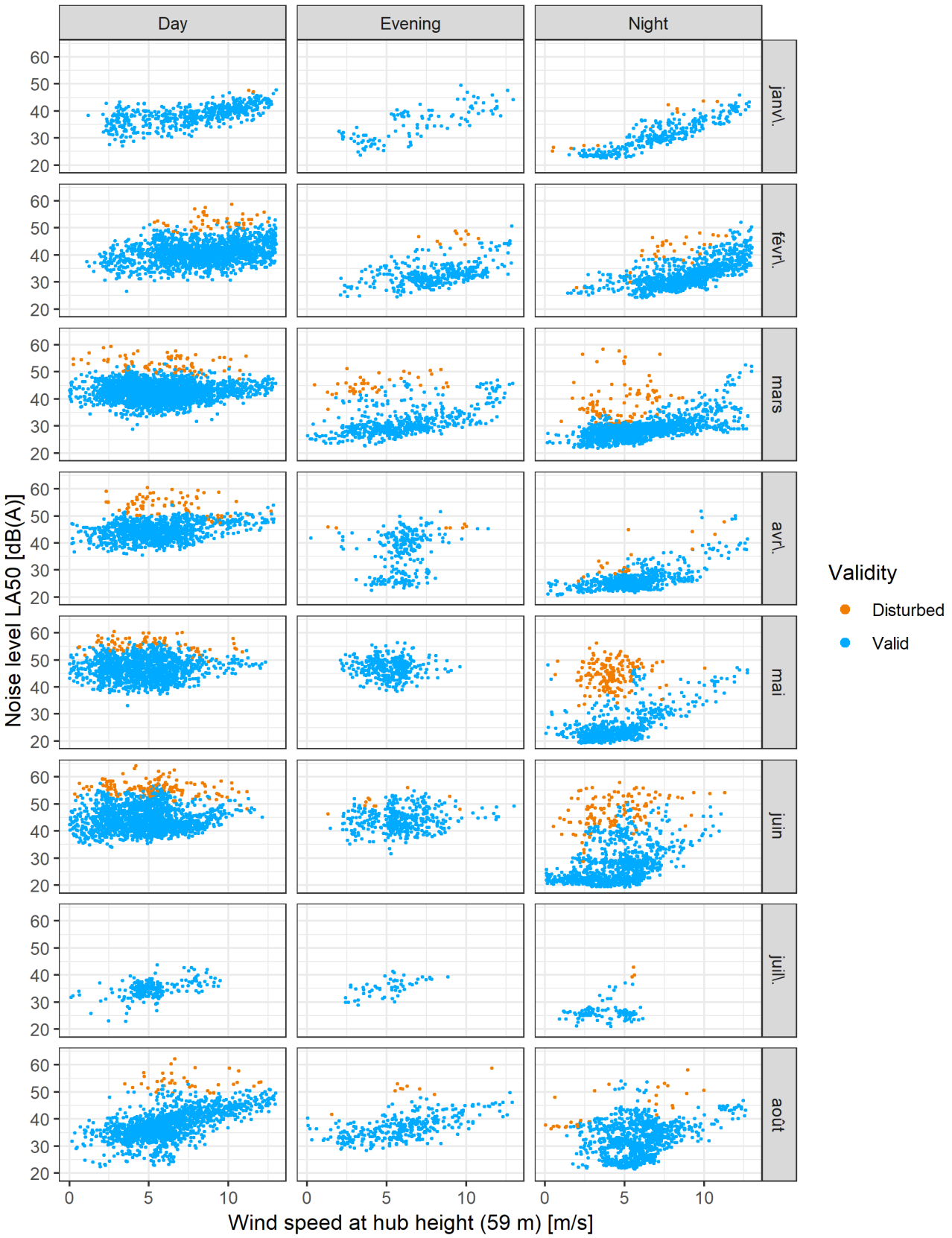

Figure 10 : Data filtering on measuring point R1

Data filtering - Location R2

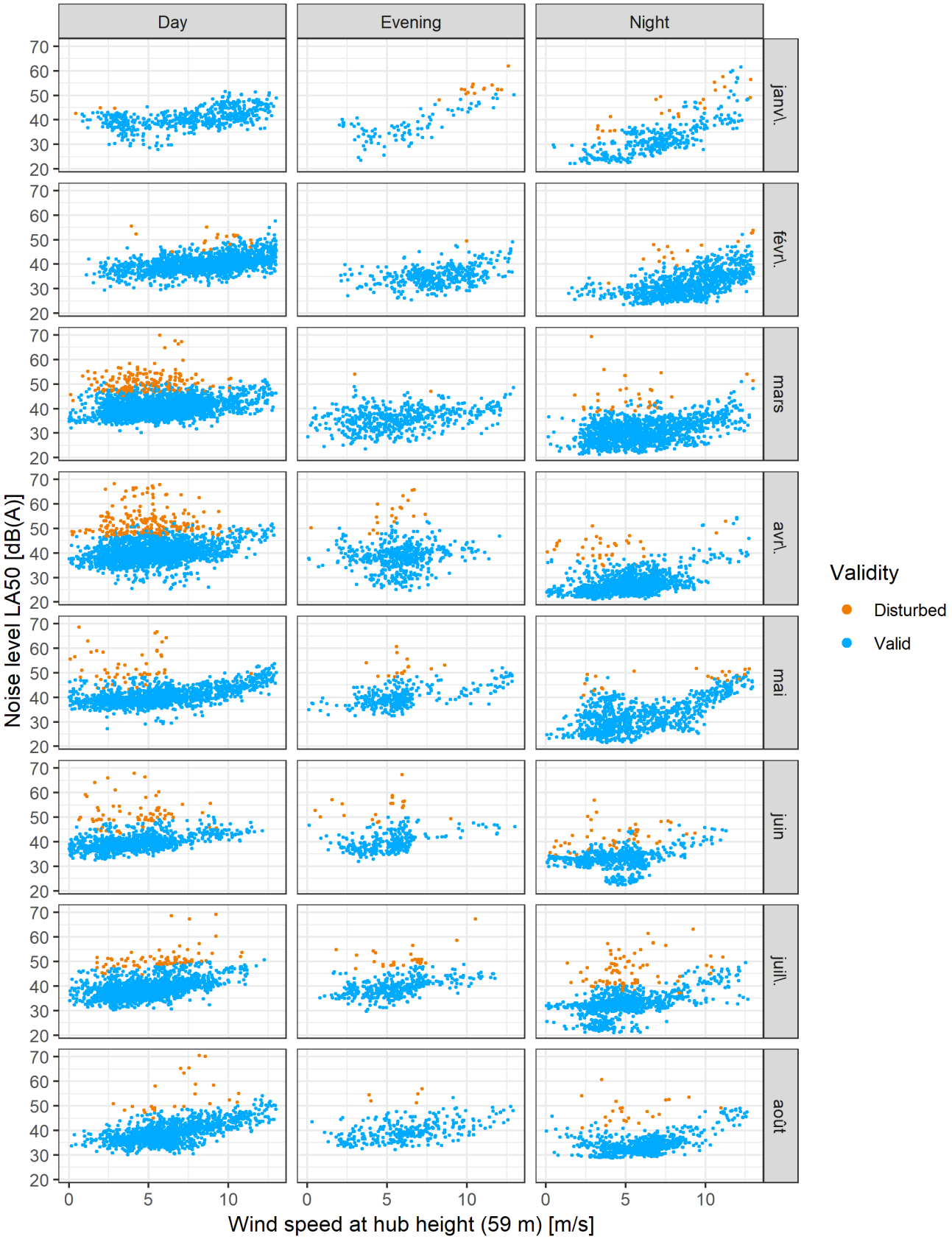

Figure 11 : Data filtering on measuring point R2