METEO FRANCE
Toujours un temps d'avance

OPERA III

WORK PACKAGE 1.5b

Site protection (wind turbines)

OPERA deliverable : OPERA_2010_05

Meteo France and SMHI – October 2010

EUMETNET
EUROPEAN METEOROLOGICAL SERVICES NETWORK

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1. Usage and importance of meteorological radars

To ensure their safety and warning missions, Meteorological services heavily and increasingly rely on meteorological radars, the only system capable of providing detailed information about the internal structure and intensity of precipitating cloud systems and associated wind fields. These radars are unique tools for monitoring hazardous events such as storms, severe wind conditions, hailstorms and heavy rainfall generating flash floods, or to determine with the highest accuracy the trajectory of pollutants resulting from industrial or nuclear incidents.

There is certainly no need to recall the dangers that can represent these various phenomena and one can remember dramatic and lethal recent events that occurred in flash floods in Boscastle in the UK, at several instances in Southern France and Eastern European countries and, more recently, on Madeira island, causing several fatalities and billions of Euros damage.

According to the World Meteorological Organization (WMO), almost 90% of natural disasters are caused by weather phenomena, climate and hydrology. These phenomena are difficult to predict, as their size is most often not exceeding a few kilometers and lifetime rarely exceeds a few hours, and only meteorological radars allow for effective observation. NWP models operated by weather services are under constant development, allowing a substantial improvement in their safety and warning missions. These models tend to incorporate observations by radar networks, allowing to derive maximum benefit.

2. Impact of wind farms on radar data

EUMETNET members quickly considered the potential threat that wind farms could cause to meteorological radar measurements. They have tried to highlight and study the possible impact on their activities (e.g. Seltmann et al. 2009, Haase et al. 2010).

These disturbances have been studied and modelled to form the basis of the EUMETNET OPERA Report (OPERA, 2006) detailing the different types of impacts (blockage of the radar beam, reflection of radar emissions that disrupts both the measurement of precipitation and Doppler winds), providing quantitative estimates and proposing measures to reduce them.

Subsequent work and in-situ measurements performed by a number of weather services and research bodies have allowed on the one hand to validate the models used and, on the other hand to highlight other critical disruption modes that were so far underestimated.

2.1 Beam blocking

When a radar transmits in the direction of a wind turbine, a portion of the electromagnetic wave is blocked by this barrier hence leading to a partial occultation of the beam. Beyond the wind farms, the signal is attenuated to varying degrees which leads to an underestimation of precipitation measurements and a loss of sensitivity of Doppler measurements.

To limit these effects, the OPERA report (2006) advocates maintaining the blocking ratio of radar beams below 10%, which corresponds to a maximum underestimation of 20 to 30% of the measurement of rainfall intensity located at 100 km.

2.2 Reflection of radar electromagnetic waves

Wind turbines reflect a large portion of the electromagnetic waves emitted by the radar, including in the antenna side lobes, thereby producing signals several orders of magnitude higher than those produced by typical weather phenomena, making any identification impossible in these large geographical areas.

These reflections result in impacts on rainfall measurements (clutter) and wind fields (Doppler effect), as described in detail in the OPERA Report (2006), for which the dimensioning factor is the Radar Cross Section (RCS) of wind turbines. The RCS is a measure for the ability of an object (or target) to reflect the waves emitted by a radar. It mainly depends on the characteristics of the signal emitted by the radar (wavelength and polarization) as well as the geometry and materials constituting the target object. It is expressed in m² (or dBsm in logarithmic scale).

Numbers of studies and measurements (e.g. QinetiQ and ONERA) have shown or confirmed that the RCS of wind turbines is very high (several hundred to several thousand square meters) and worse, that it presents extremely large and rapid fluctuations due to the rotating blades depending heavily on the orientation of the wind mill relative to the radar.

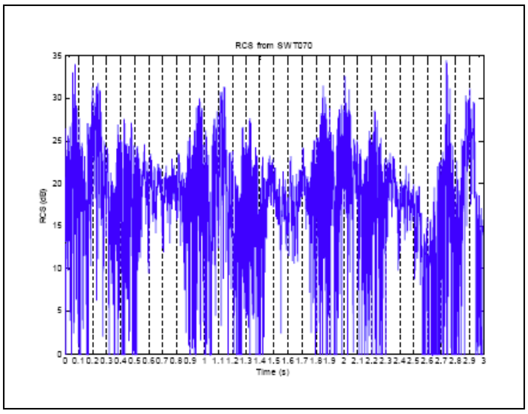


Fig. 1.a: Time variation (3s) of 3 GHz RCS of an Enercon E66 wind mill for a 39° rotor orientation (QuinetiQ, 2003).

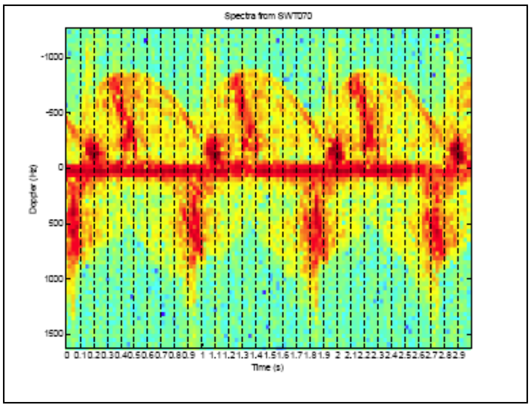


Fig. 1.b: Time variation (3s) of the Doppler spectrum of an Enercon E66 wind mill for a 39° rotor orientation (QuinetiQ, 2003).

Because of these huge RCS figures, wind turbines reflect very strong signals to the radar that can completely mask the weather phenomena to detect. The Doppler echoes induced by the rotation of the blades are not commensurate with the weather echoes in "clear sky" (power ratio exceeds 100 000, i.e. 50 dB) and prevent any possibility of wind measurements within large regions around the wind mill.

The OPERA report (2006) mainly analyzes the effect on weather radar of one single wind turbine but also stresses that the aggregated effect of wind farms is likely being more important and much more difficult to model, especially because of non-synchronization of RCS variations of each turbine.

2.2 a) Impact on precipitation data

In precipitation mode, weather radars make use of signals reflected by rain drops, hail or snow to detect and quantify rain fall intensity.

In this mode, the wind turbines echoes provide false information similar to those provided by strong storm cells (~ 60 dBz). These false echoes are typically confined to geographical areas surrounding wind farms, but the high variability of the RCS renders usually ineffective conventional treatments used for weather radars to filter "clutter". These disturbances are routinely observed in the presence of a wind farm up to distances of several tens of km (see Figures 2 and 3 below).

To minimize these impacts on precipitation data, the OPERA report (2006) recommends a "coordination" distance around the radar, coupled with a possible change in radar scanning patterns (lowest elevation, although this would limit detection capabilities for most intense precipitation events).

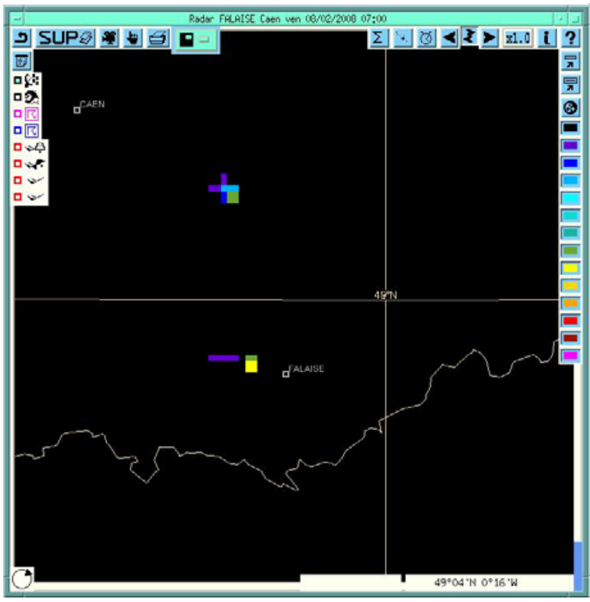


Fig. 2: **Observation on 8 February 2008. Disturbance of precipitation data in vicinity of the French radar of Falaise. North, wind farm of Conteville at a distance of 19,9 km from the radar. South, wind farm of Aubigny Soulangy at a distance of 3.5 km from the radar.**

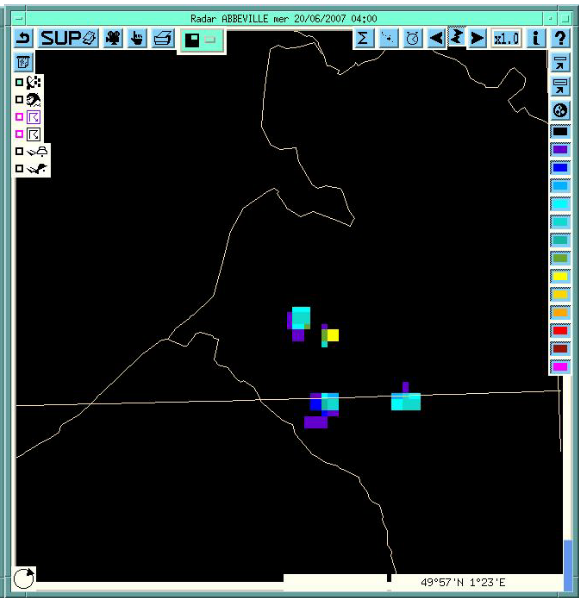
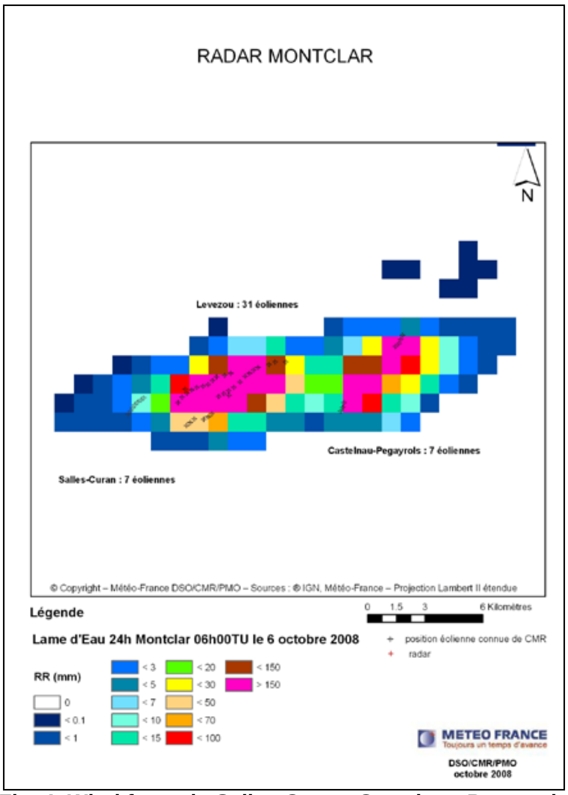


Fig. 3: **Observation on 20 June 2009. Disturbance of precipitation data in vicinity of the French radar of Abbeville by 3 different wind farms (Nibas-Saucourt, Saint-Maxent-Tilolloy and Maisnière-Tilloy-Floriville-Fretemeule). Clear sky situation without any rain.**

Among the products developed from "precipitation" data of weather radars, the QPE product (Quantitative Precipitation Estimation) is of essential interest since it directly contributes to the alerts provided by bodies in charge of hydrological survey. The QPE is to assess, over a certain period of time (a few hours to a day), the accumulated rainfall over a given geographical area. With the help of specific models, this data can then determine a number of parameters such as flood risks and, where appropriate, implement the appropriate levels of alert.

This type of product being relatively recent in operation and its sensitivity to disturbance is quite difficult to model, it was not considered in initial studies. However, the rapid development of new wind farms around radars (such as the French radar of Abbeville) has provided further insight into such an impact. Indeed, it shows a perfect correlation between artifacts of the QPE (showing accumulation of precipitation without rain) and the presence of wind farms, as well as a significantly larger size of impacted areas than those associated with ground clutter (see Figure 4 below).

To avoid measurement errors and false alarms, it is necessary to neutralize the generated data over large areas around the turbines, with two main consequences: impossibility of a formal flood warning over the affected areas and possible artifacts and false alarms associated with wind turbines whose position is poorly known or even unknown. These effects can have important consequences on the availability and reliability of hydrological and meteorological warnings developed under NWS missions of safety of life and property.

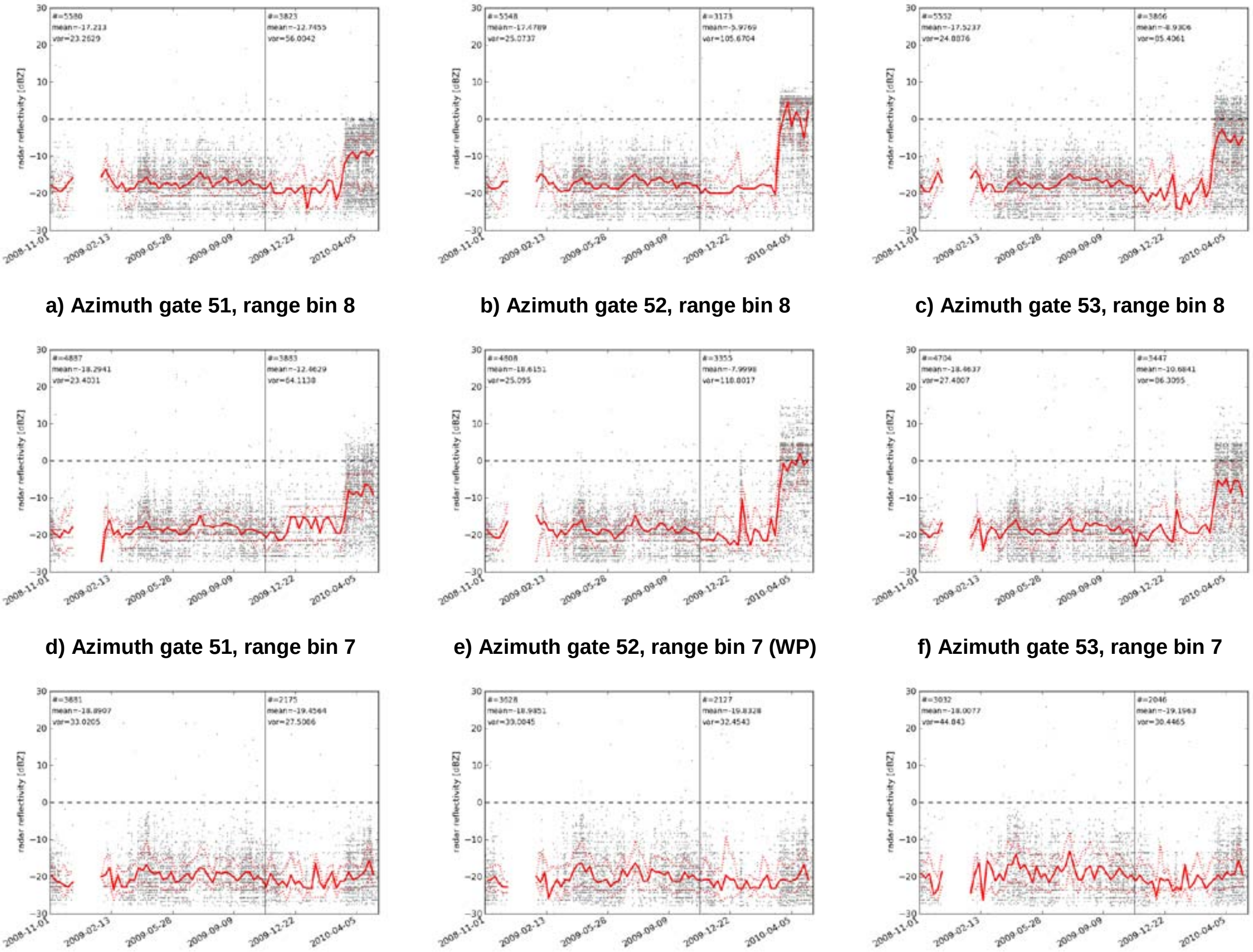


<u>Fig. 4:</u> Wind farms in Salles-Curan, Castelnau-Pegayrols and Lévezou located between 19 and 31 km from the French radar of Montclar produce an impact zone on precipitation accumulation data extending 25 km long and 5 km width. It renders data unavailable over an area of about 125 km^2.

In Sweden, the Brunsmo wind farm is located approximately 13 km north-east of the Karlskrona radar (56.30°N, 15.61°E, 123 m a.s.l.) at ca. 100 m a.s.l. (Haase et al. 2010). Five GE wind turbines each with three blades were built in October and November 2009, but due to problems with the power supply they were not put into operations before spring 2010. The hub height of the tower and the rotor diameter are 100 m, respectively, i.e. the rotor penetrates the radar beam completely under standard propagation conditions. Three out of five wind turbines are located at one single radar pixel (azimuth gate 52, range bin 7).

The beam height (a.g.l.) at the wind turbines is 123 m for the 0.5º elevation scan and 464 m for the 2º elevation scan, respectively. That means that the radar reflectivities shown in Figure 5 most likely originate from non-meteorological targets which have not been removed by the Doppler filter.

As clutter inheres a seasonal dependency it is important to evaluate radar data at least one year before and (if possible) one year after a wind turbine started producing power. Still, it might be difficult to detect clutter if the signal of the obstacle is not significantly stronger than the surrounding noise. Note that within the analyzed time period spanning from 1 November 2008 (one year before the Brunsmo wind farm has been built) to 12 May 2010, there was a major data gap at the beginning of 2009. Generally, the clutter frequency in winter is considerably lower than in summer partly due to a less turbulent atmosphere and reduced biological activity. The most noticeable phenomenon in Figures 5a-5f is the sudden rise of the noise level in March 2010 which is highly correlated with the date when the wind farm started operations. Due to overlapping beams and side lobe effects, the impact is even visible in the adjacent azimuth gates. In some cases the wind turbine blades might even cross the borderline between two azimuth gates. Clutter behind the wind farm is most likely caused by multiple-scattering between the wind turbines.



a) Azimuth gate 51, range bin 8 **b) Azimuth gate 52, range bin 8** **c) Azimuth gate 53, range bin 8**

d) Azimuth gate 51, range bin 7 **e) Azimuth gate 52, range bin 7 (WP)** **f) Azimuth gate 53, range bin 7**

g) Azimuth gate 51, range bin 6 **h) Azimuth gate 52, range bin 6** **i) Azimuth gate 53, range bin 6**

Fig. 5: Radar reflectivities around Brunsmo wind farm (WP) for the lowest elevation scan. Note that only those pixels which are wet (Z>-30 dBZ) in the 0.5º elevation scan and dry (Z=-30 dBZ) in the 2º elevation scan are shown. The solid black line refers to the assumed date of erection. The solid red line indicates the weekly median while the dotted lines correspond to the 25th and 75th percentiles, respectively. Total number of pixels, mean and variance are calculated for each period separately.

The Royal Meteorological Institute of Belgium (RMI) receives data from three C-band radars: Wideumont, Zaventem and Avesnois. Only the latter is affected by very strong echoes from some of the nearby wind farms. But also wind farms that are quite distant from the Avesnois radar (>60 km) are clearly discernable on the accumulative images.

Figure 6 shows a superposition of a 24h radar precipitation accumulation for the Avesnois radar with the location of the wind farms indicated by circles. The selected day is a day without precipitation (12 June 2009 0600 UTC – 13 June 2009 0600 UTC), so all the echoes are non-meteorological. One can clearly see a very good agreement between the bright coloured spots and the wind farms.

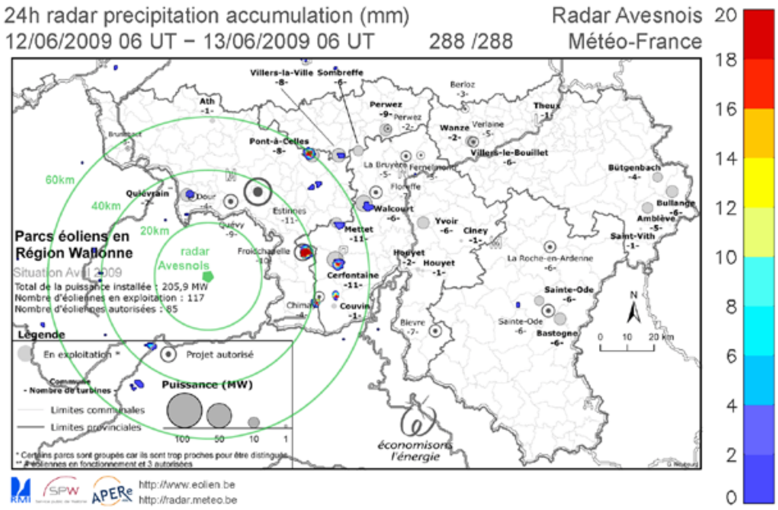


Fig. 6: **Superposition of a 24h radar precipitation accumulation for the Avesnois radar (in [mm], scale on the right) with the location of the wind farms indicated by circles. The selected day is a day without precipitation (12 June 2009 0600 UTC – 13 June 2009 0600 UTC). Image kindly provided by M. Reyniers (RMI).**

Also the UK Met Office experiences negative impact of wind turbines on their radar data. However, this is still 'early days' as they are only just beginning to witness evidence of data degradation on their weather radars and therefore are beginning to actively monitor effects with regards to beam blockages, clutter and Doppler. They have evidence of clutter from several wind farms including one wind farm (Scout Moor) which is located south of the Hameldon Hill radar and which has been responsible for triggering spurious flood forecasts. The clutter (couple of pixels) can be clearly visualised at 180 degrees in Figure 7.

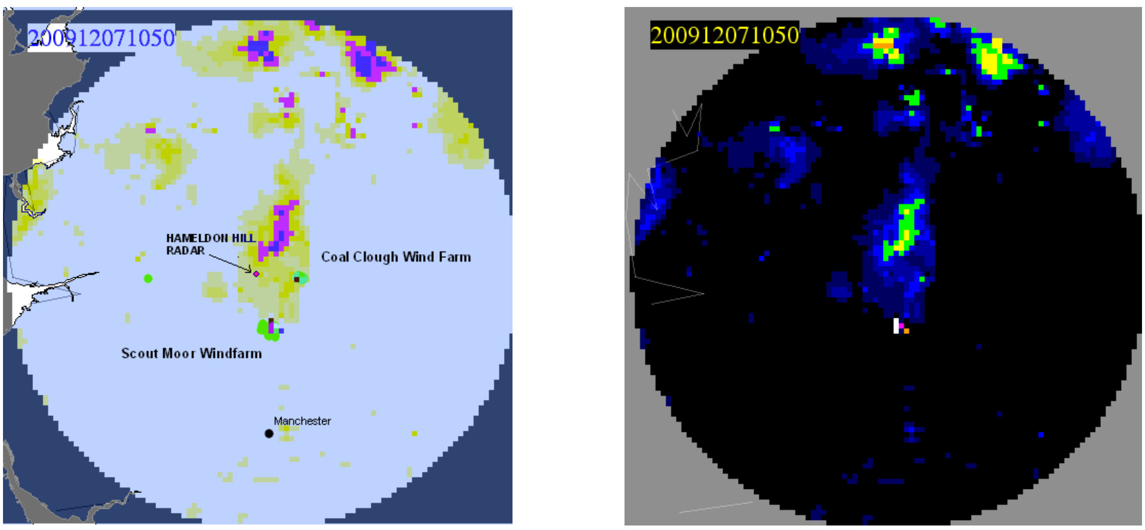


Fig. 7: **Wind turbine clutter in the precipitation (left) and reflectivity imagery (right) for the Hameldon Hill radar (UK) on 7 December 2009 1050 UTC. The resolution is 1 km. Images kindly provided by S. Holton (UKMO).**

2.2 b) Impact on Doppler data and wind fields measurements

In Doppler mode, to measure wind fields, weather radars make use of receiving signals reflected from a multitude of targets such as raindrops, ice, insects, dust or gradients of atmospheric refraction index. The radar can therefore perform measurements in both "clear sky" (about 85% of the time) and precipitation conditions. The useful signals received by the radar are generally extremely low, close to the minimum detection signal (MDS), but the measurement of their phase variations allow to evaluate the radial velocity and subsequently the wind speed.

Wind turbines, given their strong RCS and the rotation of their blades, generate a strong Doppler signal, with high fluctuations, wide range and intensity several orders of magnitude higher than those produced under natural conditions. Considering a Doppler RCS not exceeding 200 square meters, the OPERA report (2006) already highlights that the levels of spurious signals generated by the wind turbines will be such that even in the radar antenna side lobes (i.e. where the radar does not point directly towards the wind mill), the useful signals will be disrupted. Thus, areas where Doppler data are corrupted by a wind turbine are not merely limited to geographical areas where the wind mill stands but extend over very large azimuth (several tens of degrees or even 360 degrees at short distances), potentially leading to large contaminated areas. On this basis, the OPERA report advocates excluding wind farms at distances with a potential impact over 360° (5 or 10 km depending on the radar) and coordination within 20 or 30 km depending on the radar.

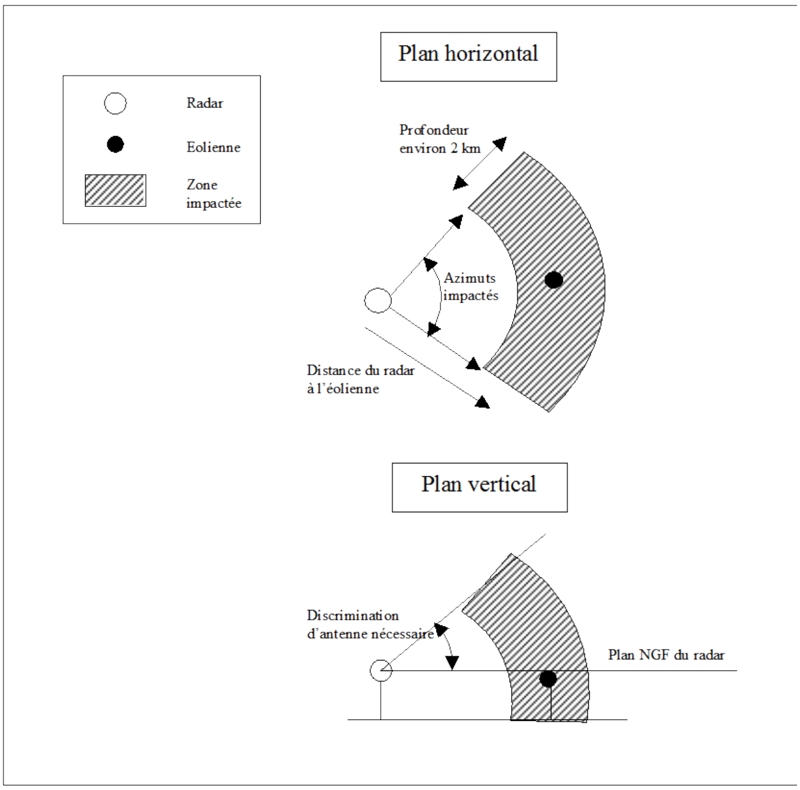


Fig. 8: Representation of the impact of a wind mill on Doppler mode

Since publication of the OPERA report (2006), meteorological services sought to confirm by observation and measurement validity of the guidelines used. These studies have for long faced the difficulty of identifying and retrieving the corrupted wind field data associated with wind turbines which direction and rotation speed also vary depending on wind conditions.

More recent studies (i.e. conducted by ONERA, the French aerospace body) have shown that in some configurations, the RCS values of wind turbines in Doppler mode, considered initially at 200 m² on an average basis, could reach, during very short time, extreme values the order of 100 000 m² (or 50 dBsm), i.e. 500 times larger.

In particular, the specific case of the French radar of Abbeville, around which a large number of wind farms have already been implemented, has large Doppler impact areas, arched crown concentric (consistent with those predicted by the initial model), in which observed wind data are inconsistent, random and of noisy nature, and therefore totally unusable.

In Figure 9 below, the highlighted data are Doppler wind speeds acquired with a radar elevation angle of 1.3 degrees that represents, at the respective areas where wind farms stand, an average altitude of about 500 m, well above the uppermost height of wind turbines of 200 m. Similar persistent results have also been obtained at higher radar elevation angles, reflecting a volume dimension of the impact zone, here also consistent with the initial model.

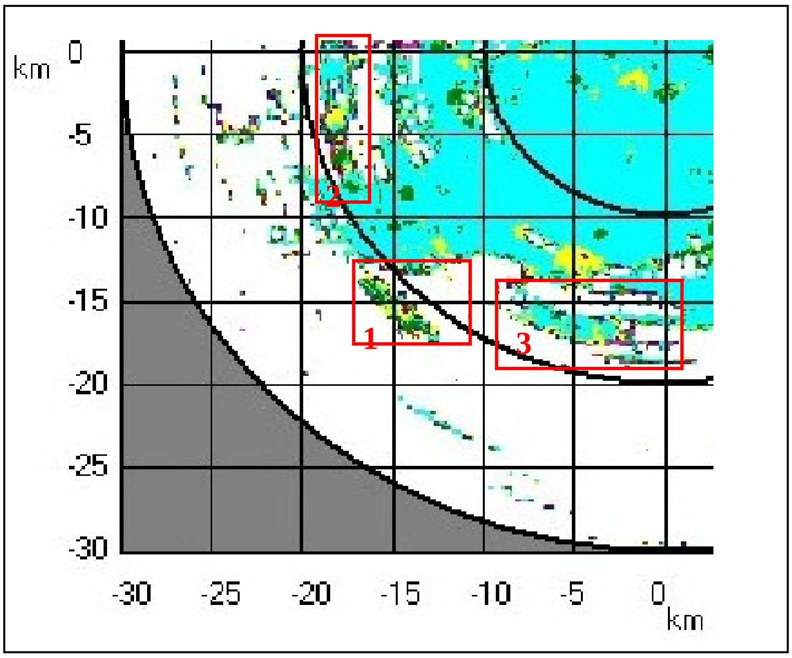
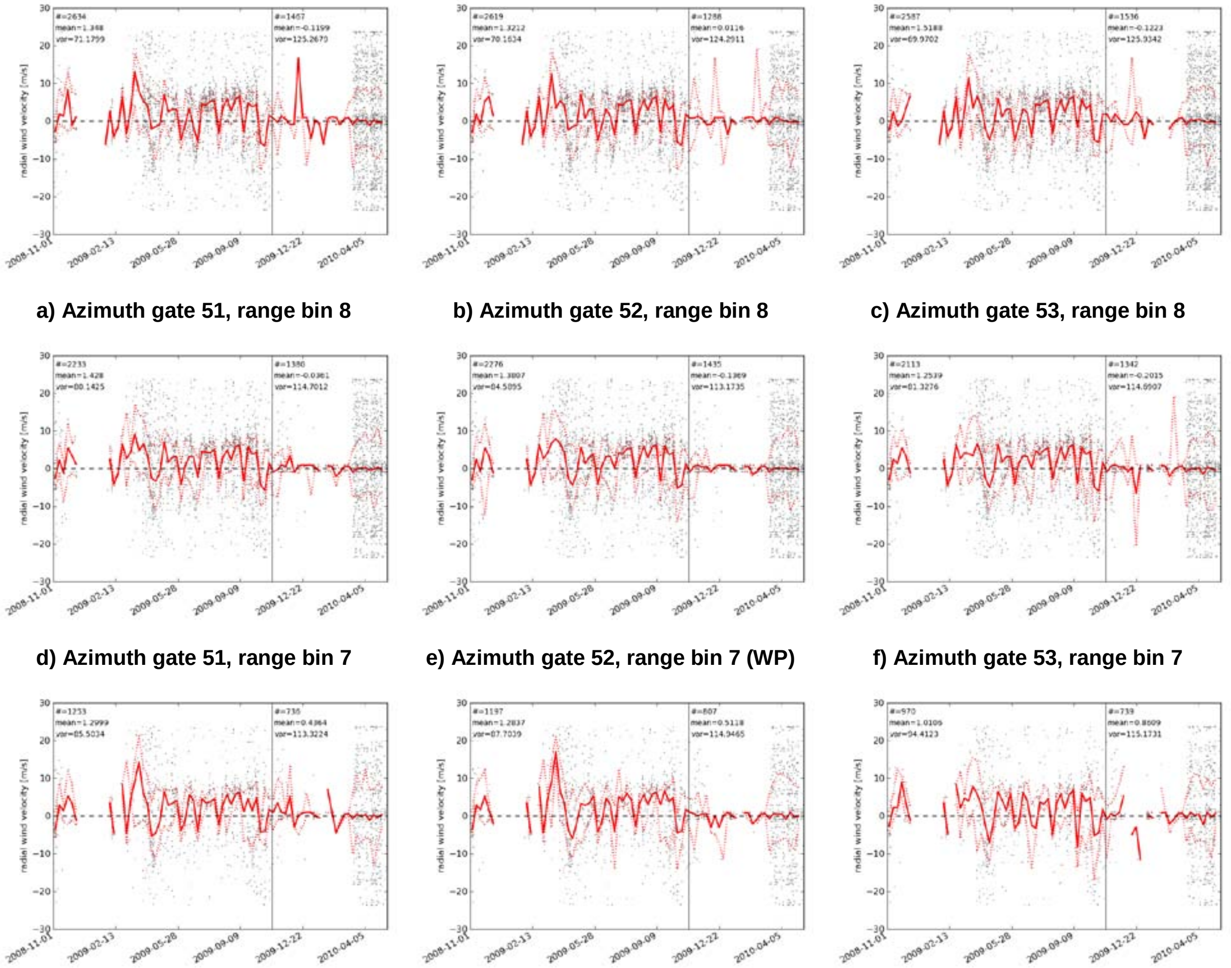


Fig. 9: **Detailed Doppler measurements observed for 3 wind farms located south-east from French radar of Abbeville.**

Of particular note is the significant disruption caused by the wind farm No. 1 which is located beyond 20 km recommended for coordination. Moreover, the characteristic dimensions of the disturbed areas have the same order of magnitude (few km to some tens of km) as severe weather events such as thunderstorms generating floods, hail, high winds or tornadoes.

The impact of wind turbines on Doppler wind measurements is illustrated by an 18-month time series of clear-air radial wind velocities for the Brunsmo wind farm in Sweden (Haase et al. 2010). The sudden rise of the reflectivity noise level (Figures 5a-5f) coincides with a significant increase of the Doppler velocity spread (Figures 10a-10f) resulting in a median velocity close to zero. This is probably due to the superposition of the nine blade velocities. Beam overlapping and side lobe effects are visible in the adjacent azimuth gates.



a) Azimuth gate 51, range bin 8 b) Azimuth gate 52, range bin 8 c) Azimuth gate 53, range bin 8

d) Azimuth gate 51, range bin 7 e) Azimuth gate 52, range bin 7 (WP) f) Azimuth gate 53, range bin 7

g) Azimuth gate 51, range bin 6 h) Azimuth gate 52, range bin 6 i) Azimuth gate 53, range bin 6

Fig. 10: As Figure 5 but for radial wind velocities.

These observations show that the coordination distances recommended so far in OPERA already represent a compromise between the need to protect meteorological radars and the willingness not to overly constrain the deployment of wind farms. They may under no circumstances be considered as distance limits beyond which the impact of wind turbines become negligible. One can stress that such impacts have led some countries to establish coordination distances significantly larger, e.g. 80 km in Canada.

The relevance of initial models described in the OPERA report (2006) is therefore widely confirmed and validated by measurements.

2.3 Possibility to filter-out corrupted data

Many studies have been performed to consider possible solutions to filter-out corrupted data induced by wind mills (e.g. Isom et al. 2009, Gallardo-Hernando et al. 2010, Hood et al. 2010). The options however currently seem pretty limited, mainly for technological reasons. The blocking effect of the radar beam cannot be fixed as it induces in the downstream areas of a wind turbine an attenuation of the signal received by the radar.

Considering the impacts produced by the reflection of radar waves ("precipitation" and "Doppler"), the issue is of a different nature since, although largely overlaped in both intensity and phase by reflected signals from wind mills, the useful atmospheric signals are still received by the radar.

Unfortunately, given the characteristics of the disturbances caused by wind turbines (see Figures 11 and 12) and the current state of the art of available technology, it seems quite unrealistic (especially in Doppler mode) to filter the received signals to retrieve the useful atmospheric part (constructive filtering).

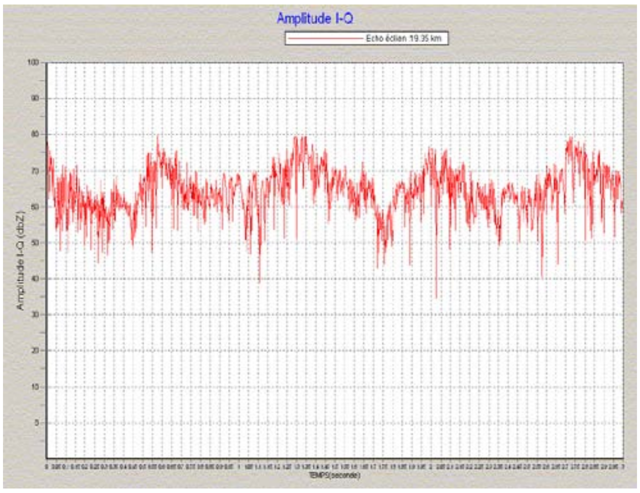


Fig. 11: **Reflectivity converted from power signal received from a wind mill located 19 km from French radar of Falaise.**

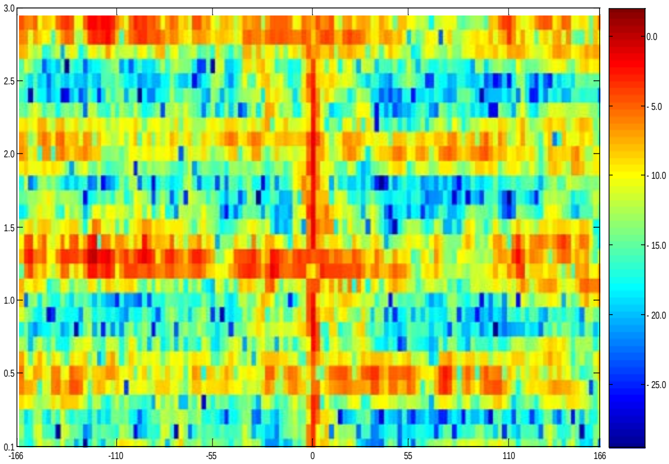


Fig. 12: **Falaise 8 October 2008 13h35. Time evolution (3s) of the Doppler spectrum from a wind mill located 19 km from French radar of Falaise. The color scale represents the values of amplitude of the received power in dB relative to the maximum observed over the measurement period. The central axis (0Hz) corresponds to echoes associated with non-mobile elements present in the measurement volume.**

Facing this issue, the currently only practicable solution is the use of masking, i.e. to delete all data in areas potentially impacted by wind turbines (destructive filtering).

However, this “filtering” technique has significant drawbacks, which, in extreme cases may render meteorological radars inoperable. It requires knowledge and consideration of all existing wind mills, the lack of data of a single turbine implies the risk to negate the effectiveness of the whole filtering process.

Moreover, the current poor knowledge of wind turbines RCS will also require to overestimate the size of masking areas whereas in QPE and "Doppler" modes which correspond to large areas of disturbance, masking one single wind farm already lead to an important data loss. Depending on the density of wind farms around the radar, this technique could potentially lead to loosing data over large areas and render the whole data totally unusable.

2.4 Other solution to mitigate wind mills impact

Some solutions to mitigate wind mill impact on meteorological radars relate to the operation of radars themselves whereas others could be applied to wind turbines implementation and structure.

Operating radars in degraded mode (decrease sensitivity or increasing elevation of the radar over wind farms) can probably limit the impact of the corresponding clutter but, as confirmed in the OPERA report (2006), this method remains totally ineffective for wind measurements (Doppler) and QPE.

One could also consider that limiting wind turbine RCS making use of absorbent materials or paint or a specific design of the structure, similar to what exists for military aircraft, could probably improve coexistence situation. It seems however that, although some research are currently performed in this direction, there is yet neither conclusions showing a potential important mitigation nor manufacturer providing wind mills presenting such characteristics.

3. Impacts on meteorological products

The important impact of wind turbines on radar data, demonstrated and validated by both modelling and measurements, ultimately leads to the inclusion of erroneous or partial data in forecasting and warning processes which can in turn affect the current meteorological products or jeopardize the development of new products.

3.1 Weather forecast

The use and assimilation of data from weather radars in high resolution NWP models is already operational in a number of meteorological services with the integration of "wind fields" and reflectivities. The impact of these new data on forecast accuracy and reliability was assessed using objective indicators that show a significant improvement in short-term forecasts, essential in warning processes, as complement to nowcasting.

Although the usefulness of these data is of no doubt, it is however too early to specifically assess the impact of erroneous or missing radar data on forecasts. Indeed, the multitude of possible weather situations would necessitate the analysis of simulations over a very long period, probably years. However, we can reasonably estimate that a significant lack of "wind field" data around weather radars would jeopardize the improvements as reported today.

Finally, the consideration of radar data is an important decision element for forecasters themselves. Indeed, in parallel of the data resulting from the NWP model real-time radar data images allow them to compare and constantly refine the actual weather situation, especially when monitoring potential convective critical situations.

3.2 Hydrology

Precipitation data and QPE support the management of water resources and are used directly by the relevant authorities to monitor flood risks and issue hydrological warnings.

Although impacts of wind turbines on instantaneous precipitation measurements beyond 10 km from radars are most often minor, the situation is dramatically different for QPE calculated from the accumulated precipitation over several tens of km² which could substantially be overestimated due to wind farm impact.

A number of sensitive locations known for flash flood risks or presenting specific industrial installations should be kept clear from any wind turbines. Otherwise, masking data would considerably reduce the quality of information necessary to produce hydrological warnings, whereas a lack of masking could create false alarms that would put into question the overall reliability of the process. So, specific areas subjected to flash floods or which foster stationary precipitation events due to their relief, should justify special protection measures such as prohibiting the implementation of any wind turbine between the radar and those areas.

3.3 Pollution and industrial and nuclear risks

Applications that support risk management, industrial or nuclear incidents are of specific nature. Indeed, such an incident may occur at a time where the weather situation does not present any danger, hence deserving no attention from forecasters. In a context of crisis or post-incident analysis, the authorities are particularly interested in atmospheric transfer coefficient (ATC) maps which indicate the spatial extent of the incident and expected pollution consequences on food chain or water quality, to take the necessary measures to protect the population.

The concentration of an accidental release in the atmosphere is driven by wind (direction and strength), atmospheric stability and the possible precipitation. It is obvious that local alteration of a "wind field" due to missing or erroneous data could affect the ATC pollution mapping, with important consequences in critical cases such as dangerous pollutants near an area with high population density.

A comparison analysis of optimal and degraded radar observations (according to different scenarios) could probably allow to quantify and locate areas for which important differences would be experienced, to better characterize the risk of getting weather information deteriorated over sensitive industrial sites, to assess the maximum exposure and to roughly estimate the corresponding probability. However, such analysis would require to perform simulations over a long period of time before getting a sufficient number of occurrences. Such a delay is hardly compatible with the current rapid and uncontrolled deployment of wind farms and could potentially lead to a severe contamination of radar data and make them unusable. One can however already assume that erroneous data will rapidly affect the quality of alerts to ensure the safety of persons and property and the situation is even more critical as the relevant areas are not necessarily subject of special attention.

3.4 Medium and long-term products

All weather services provide a constant development of their products to meet the need and growing demand from the authorities and the population in terms of forecasting and early warning.

Improving forecasts is in particular implemented through joint development of NWP models at shorter scales and assimilation of spatially consistent data from observing systems.

A number of developments are on-going or in prospect, based on data from weather radar and, of course, the assumption of optimum availability of the data:

- Determination of winds at low level and the onset of convection ;
- Detection of wind shear, critical for monitoring events like tornadoes hazardous to aviation safety ;
- Detection of hail and supercooled water through the use of polarimetric data ;
- Improving early-warning process through "warn-on-forecast" systems to allow nowcasting of dangerous weather events based on both prediction and observation at short scale

NWP models are becoming more and more powerful and need increasingly detailed and precise data. The impact of assimilation of wind observations by radar was quantified at different instances. As an example, scores of the Scandinavian NWP system (HIRLAM) for 24h forecasts have been dramatically improved, registering in some cases, a reduction of the mean square error of prediction of wind up to 20 to 25%, empirically translated into a 2 to 3 hours gain on prediction (Figure 13).

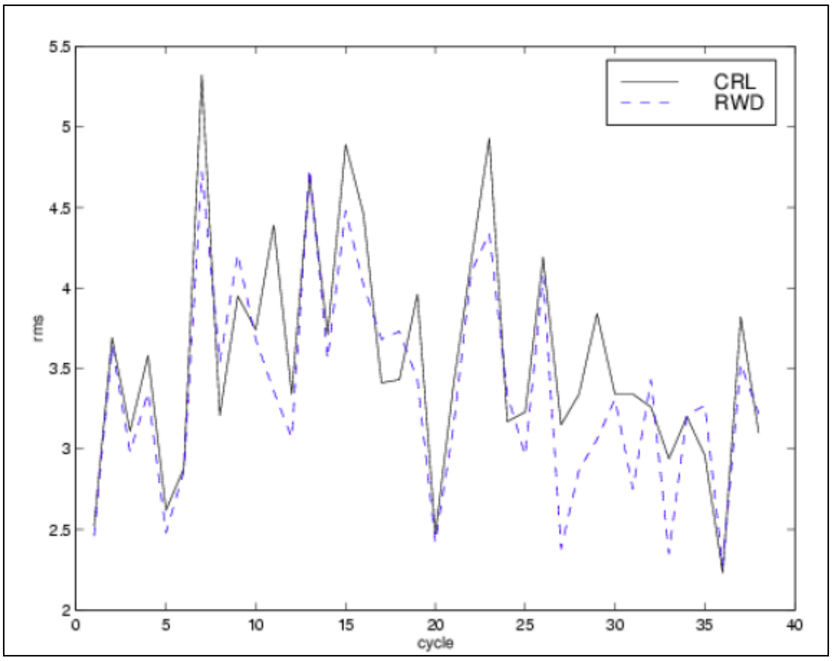


Fig. 13: RMS forecast verification scores for 700 hPa wind speed, verified against radiosonde data, from experiment with (RWD) and without (CRL) radar radial wind super-observations. The data period is 1 – 10 December 1999.

Most current short scale NWP rely on the quality of wind field measurements provided by weather radars and it is more than likely that, in response to the increasing expectations of users, the operational system will provide forecasts at shorter scales for which wind observations by radar will represent an increasingly important source of data, which could rapidly be affected by uncontrolled development of wind farms.

Nowcasting is another rapidly developing activity that already or will rely on quality of radar measurements. Among future products that could suffer from uncontrolled development of wind turbines, one could cite:

- Automatic warning messages intended to indicate storms and the probability of occurrence of tornadoes (on the basis of detection of a meso-vortex) and hail (based on radar measurements using polarization diversity)
- Forecast of supercooled water responsible for airplane or road icing
- Detection of turbulence and wind shear in the vicinity of airports. This is a current component of the European programme SESAR especially appealing to a large number of weather radars.

4. Conclusions

A weather radar is a unique instrument capable of real-time display of high resolution precipitation and wind field data. It is an invaluable tool to meet the increasing need for reliable predictions in spatial and temporal scales in terms of vigilance and alert in the meteorological and hydrological domains, covering in particular industrial and nuclear risks or aeronautical safety.

The impact of wind turbines as described in the OPERA report (2006) has since been validated through experience and is internationally recognised, in particular within the International Telecommunications Union in its Recommandation UIT-R M.1849.

Only a strict application of the OPERA recommendations (exclusion distance of 5 or 10 km and coordination distances of 20 to 30 km for C- and S-band radars, respectively) could allow European weather services to keep radar capabilities consistent with their public missions (cf Statement of the OPERA group on the cohabitation between weather radars and wind turbines in appendix).

In particular, a number of sensitive areas (subjected to flash flood or pollution risks) requires a specific attention due to their potential dramatic impact on the population.

In some cases, it is well known that the development of wind farms around radars already partially jeopardize their observation capabilities and new wind farms projects pose a significant risk on other radars. One can already assume that prediction, surveillance and warning systems may already be altered. In the longer-term, poorly controlled development of the wind energy would clearly represent a threat to the capacity of improvement and development of new warning systems.

Corrupted data can in some areas, within certain limits, be masked or compensated by extrapolation systems. However, these techniques require the maintenance of a sufficient number of reliable and therefore not corrupted data, thus requiring a strict control and limitation of future wind-farms in the vicinity of weather radars.

It seems important to stress that, according to the OPERA recommendation and for typical radar deployment, exclusion zones around weather radars represent less than 1% of the territory and coordination areas less than 8%.

These elements justify the necessity and urgence to establish a global regulatory framework to ensure a peaceful coexistence between weather radars and wind turbines.

5. References

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Appendix

Statement of the OPERA group on the cohabitation between weather radars and wind turbines

The OPERA group of EUMETNET :

- Considering the studies showing that the impact of wind turbines on weather radars are of three main types :

  - beam blocking
  - clutter
  - Doppler mode

- Considering the experience of cohabitation of European Meteorological Services, in particular Danish Meteorological Institute (DMI), Deutscher Wetterdienst (DWD), National of Meteorology of Spain (INM), Royal Netherlands Meteorological Institute (KNMI), Météo-France and UK Metoffice,

- Considering that the most critical impact of wind turbines concerns the Doppler mode,

State :

1) that no wind turbine should be deployed at a range from radar antenna lower than:

  - 5 kilometers for C-band radars
  - 10 kilometers for S-band radars

2) that projects of wind parks should be submitted to an impact study when they concern ranges lower than :

  - 20 kilometers for C-band radars
  - 30 kilometers for S-band radars

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