COEXISTENCE OF METEOROLOGICAL RADARS AND WIND FARMS: SUCCESSFUL OPERATIONAL STORIES

Daniel Sempere Torres[1], Marc Berenguer[1] and Isztar Zawadzki[2]

[1]Centre de Recerca Aplicada en Hidrometeorologia, CRAHI-UPC, Barcelona (Spain); [2] McGill University, Montreal (Canada)

Wind Turbine and wind farms impact on meteorological radars

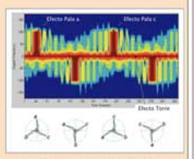
Wind farms impact over the dual polarimetric Vaisala radar of MeteoGalicia in a non-rainy day. The Photo shows the wind turbines of the wind farm located at the Seixo-Cando mountain.

In the last years, the concern on the impacts of wind farms on the measurements of the meteorological radars is on rise.
Their main impacts are :

(i) The clutter caused by the **combination of the wind turbines with the orography in which they are located**. As the turbine clutter has a speed component due to the **rotation of the blades**, their combination **overpasses the usual clutter filters just based on the analysis of the Doppler velocity spectrum.**

(ii) The areas of under-detection potentially generated by the partial beam blockage they are supposed to cause.

The rotation of the blades causes important effects over the Doppler velocity spectra, thus the clutter cannot be eliminated by Doppler filters.



Source: Lok et al. (2010)

A huge number of studies characterising the effects on the signal have been carried out

- First diagnosis studies
  - UK Royal Air Force, 1994, 2005
  - Air Force Research Laboratory, 2006
  - US Department of Defense, 2006
- Operation recommendations
  - Vogt et al. 2007, 2009, 2010, 2011
- Characterizing impacts through observations
  - Burgess et al., 2008
  - Haase et al., 2010
  - Seltmann et al., 2010
- Characterizing impacts through simulations
  - Gallardo-Hernando, 2008, 2010
  - Lok et al. 2010
  - Kong et al., 2011
  - Zhang et al. 2011
- Automatic detection of turbine clutter
  - Hood et al., 2010

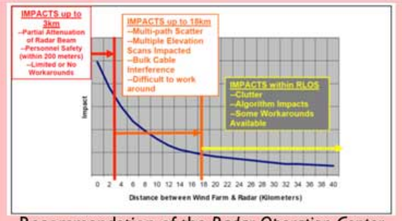
some proposing mitigation strategies

- Mitigation studies
  - Palmer et al., 2008
  - Bachmann et al., 2010
  - Nai et al. 2011
  - Isom et al., 2011
- Gapfiller solutions
  - Aarholt and Jackson, 2010

but.... very few operational solutions available up to now

The comprehensive study of the US Department of Defense study (DoD, 2006) identified the **need to promote research and development of advanced processing methodologies** able to address the impact of wind turbines in the future, and to allow the coexistence of radar and wind farms. Since then, a big number of studies have been carried out, but the majority of them are theoretical or laboratory studies. **VERY FEW OPERATIONAL STUDIES ARE AVAILABLE leading to a systematic overestimation of the supposed impacts.**

What are we doing in case of new Wind farm developments near a Radar site?



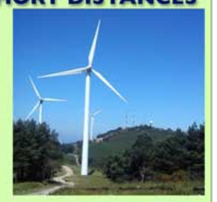
Recommendation of the *Radar Operation Center* (ROC) of the US *National Weather Service*

< 3 km	3 to 18 km	> 18 km
No Permission	No Permission if in Line of Sight	Permission OK although in line of Sight

In Europe EUMETNET has agreed a similar recommendation, what in fact **leads to NOT ALLOWING ANY NEW WIND FARM DEVELOPMENT AT LESS THAN 20 km from any radar.**

Is this **THE** solution?

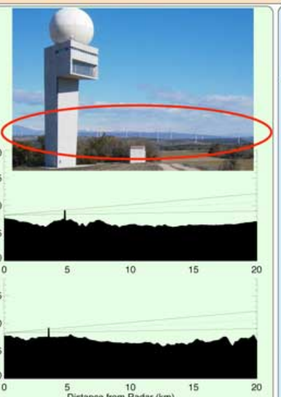
BUT THERE ARE RADARS WORKING OPERATIONALLY WITHOUT PROBLEMS EVEN WITH TURBINES LOCATED AT VERY SHORT DISTANCES



Can we learn from the successful operational stories to improve the present processing and allow the FULL COEXISTENCE BETWEEN RADARS AND TURBINES?

Operational application in Catalunya (NE Spain)

The CDV C-band radar of METEO.CAT is affected by a number of wind farms located at short distances, with dozens of **turbines located at less than 5 Km and some of them even closer than 3 km**.
The products based on conventional filters using Doppler velocity spectrum (IRIS software in this case) are not able to mitigate the effects of the Wind Turbines located on the Line of Sight of the radar, both in non-rainy and rainy periods.



IRIS output 2013-09-09@14:54 UTC (standard commercial processing based on Doppler filter) cannot mitigate the effect of wind farms. Screen capture of the operational product at http://www.meteo.cat/servmet/radar/cdv.html

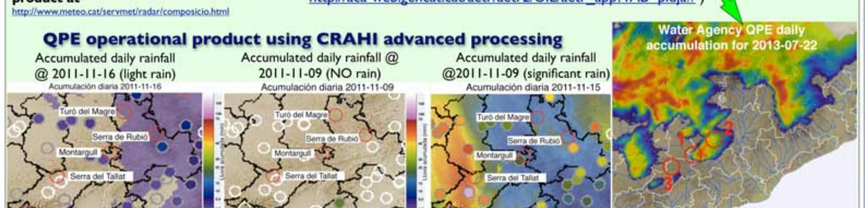
Examples of Turbines from the Montmaneu and Civit Wind Farms, and interception of the Radar Line of Sight (**total interception of the 1° beam**)

Screen capture from corrected operational product at http://www.meteo.cat/servmet/radar/composicio.html

The use of advanced processing not just using Doppler velocity spectrum (EHIMI algorithms from CRAHI) allow to discriminate the turbine echoes and to mitigate their effects into the radar products.
Their **operational** use in METEO.CAT radars shows that **wind turbines, even at less than 3 km, have no effects on the radar products if the correct processing is applied.**

The **accumulated daily rainfall products show NO TRACES of wind turbines both for rainy and non-rainy periods**.
The QPE rain gradients over the concerned areas look unaffected and the regional accumulated rainfall products using raingauge combination show that the wind farms **are not a problem for the meteorological radar operation**. (see the Water Agency hourly and daily operational products at http://aca-web.gencat.cat/aetr/aetr2/UIL/aetr_app?TAB=pluja#)

QPE operational product using CRAHI advanced processing

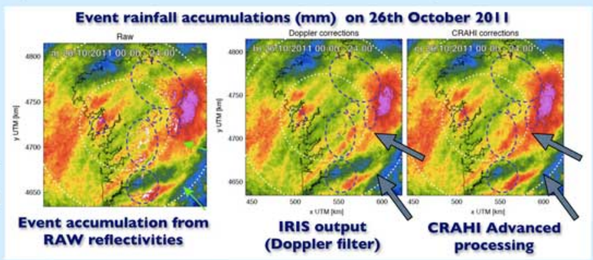


The circles show the raingauge observations in the same colour palette than the radar

Operational application in Galicia (NW Spain)

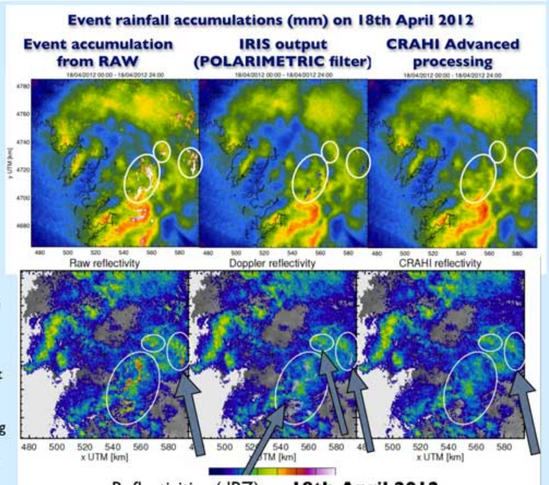
The Vaisala Dual-Polarimetric C-band radar of MeteoGalicia is affected by a number of wind farms located at short distances. New wind farms are planned at less than 10 km, what has leaded to study if they can affect the data quality of radar products.

In 2011, the products based on **conventional filters using Doppler velocity spectrum** (IRIS software) were **not able to mitigate the effects of the existing Wind Turbines** even during non rainy periods. However the application of the CRAHI advanced software (Berenguer et al. 2006) was able to remove the effects of the wind farms even over daily rainfall accumulations.



The use of an **improved POLARIMETRIC FILTER** in the IRIS software since mid 2012 has shown that the **wind farm echoes can be easily removed using commercial software** if additional information to those provided by the Doppler velocity spectrum is used.

After this software improvement, the **wind turbines echoes do not appear any more**. However, accumulated rain products show that the present version of the filter is still not able to conveniently **restore the continuity of the rainfall field**.
This can be easily seen in the comparison of the reflectivities, where the echoes due to the combined effect of OROGRAPHY + WIND TURBINES are now efficiently identified and removed.
However the IRIS polarimetric filter is still not able to estimate the rainfall over these pixels and the accumulated values are inaccurate.
The CRAHI advanced processing is performing better even without the use of polarimetric data, showing that **there is room for new operational improvements in the next years.**



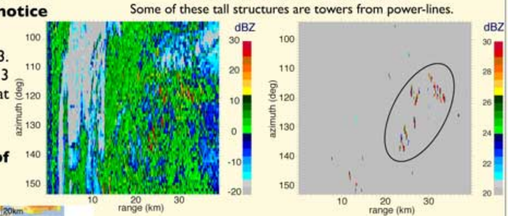
Operational application in Montreal (Quebec, Canada)

View of the turbines from the radar tower.
Some of these tall structures are towers from power-lines.

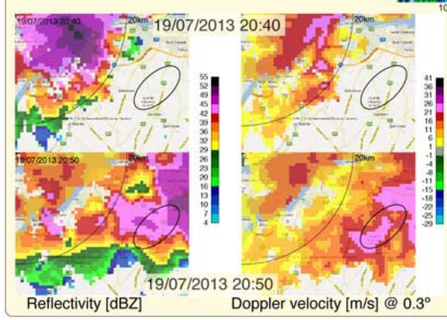
THE McGILL EXPERIENCE
In the course of 2012/13 a network of 50 wind turbines were installed at 20 to 35 km from the McGill S-band radar. **Operational forecasters did not notice any change in data quality.**

At left hand side, a reflectivity image during 2013.
At righthand side, dBZ difference between 2013 (after deployment) - 2011 (before deployment) at 1°x125m resolution.
The ellipse delimits the region of turbines.

Note the absence of blocking and of multiple scattering.



Difference between echoes before and after the turbines installation.



Two times of 0.3° PPIs during precipitation. Ellipses indicate the location of turbines.
After clutter removal through target ID **there is no trace of turbines contamination**.

Conclusions from this experience:
At these ranges, problems with wind turbines are more a result of an inadequate signal/data processing within present radar capabilities than of the turbines themselves.

Acknowledgements

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