

Abstract

In order to assist local authorities and wind energy developers, the French Environment and Energy Management Agency, ADEME, has sponsored an updated assessment of the wind resource in France.

Meteolien, a technical SME specialized in wind resource and wind energy production assessment, has joined with Météo-France, the French national meteorological service and Magellium, a GIS company, to address this challenge.

The improvement of Mesoscale modelling in resolution and also in the representation of physical phenomena such as convection provides a valuable tool to generate long term wind data series at a kilometric resolution. Data assimilation all along the simulation increases its consistency with wind observations.

Combining both approaches of Mesoscale modelling and CFD modelling over complex topography areas leads to reliable production assessment for wind power plants.

Objectives

- The main objectives are:
- To produce an up-to-date wind atlas for France, French West Indies and New-Caledonia combining best properties of Mesoscale and CFD models
 - To provide end-users information about the uncertainty of the assessed parameters
 - To allow new sourcing data acquisition way for power plant long term and short term production assessments

Methods

AROME dynamical downscaling simulation

The French numerical weather prediction model, AROME, is used to generate **wind time series** :

- 2.5 km horizontal resolution
- 60 vertical levels
- at a hourly time-step
- for 15 years, 2000 - 2014

Output time-series = 10 years long-term simulation + 5 years oper runs

Long-term simulation 10 years 2000 - 2009

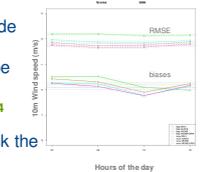
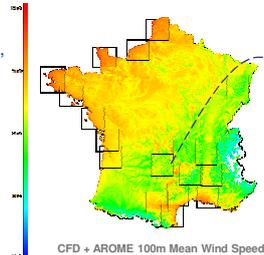
The dynamic downscaling process is the following:

ERA-I (80km) → ALADIN (15km) → AROME (2.5km)

It includes a 6h surface analysis cycle in ALADIN to provide high consistency with observations of onshore surface parameters, from 2500 measurement stations over Europe

Concatenation with operational archive 6 years 2009 - 2014

The two data-sets share year 2009 that was used to check the consistency of both data-sets.



CFD500 downscaling method

This method allows to go from a grid of 2,5kmx2,5km to a grid of 500m x 500m. The two models are coupled dynamically. On each zone of 100km x 100km, several points of references are chosen in the AROME data set, following the high similarity of the two models physical environments.

CFD model is then forced on this points and run over 8 heights (20m to 160m). The CFD model takes the AROME data sets as inputs for downscaling, integrating detailed terrain numerical models and wind turbines characteristics in the same way as it would be done in the traditional long term production assessment.

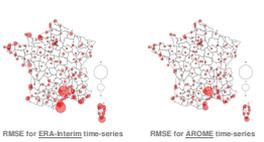
- Some variables result directly from the CFD500 model, as:
- Long term mean wind speed (15Yrs)
 - Long term mean energy density (15Yrs)
 - Weibull distribution A,k factors (15Yrs)

Some other variables are the result of a weighted or statistical redistribution of the AROME data sets on a 500mx500m basis.

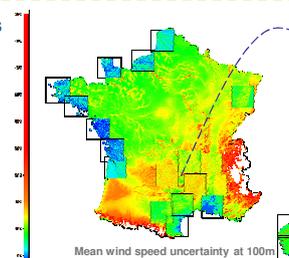
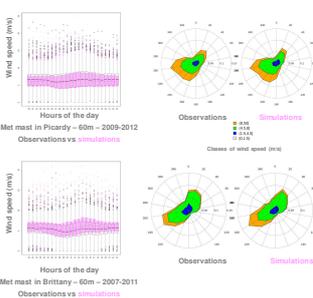
- This is the case for:
- Short term variables (24h standard deviation, hourly acceleration standard deviation)
 - Long term variables (monthly mean wind speed over 15Yrs) and,
 - Confidence intervals

Verification of AROME simulated time-series

Wind Speed - Simulated time-series vs observations at 10m height - 2000 - 2009



Hourly wind Speed - Simulated time-series vs observations at 60m height



Uncertainties assessment with a Bayesian approach

The assessment of uncertainty relies on a Bayesian statistics approach.

Bayesian inference approach requires specification of prior distributions for mean wind speed.

Prior distributions are quantified according to a former ALADIN wind atlas and its known errors in comparison with wind speed observations at 10m height.

Choice of the zones to be treated in CFD500:
 The 20 zones to downscale have been chosen following:

- The complexity of the topography / roughness.
- The zones with islands and complex coasts.

And to reduce the number of zones to only 20, priority has been given to the zones with the highest wind potentials.

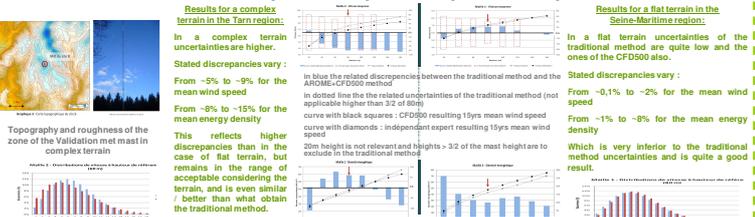
Reduction of the uncertainties by the CFD500 downscaling

At the level of each 500m x 500m mesh appear 3 sources of - Uncertainties related to the CFD model itself (that is calculated directly as output of the model),

- Under-mesh uncertainties (including topographical and roughness evolution within a mesh) and,
- Data sources uncertainties.

The uncertainties are reduced if compared to the same zone with AROME, by multiplying the number of reference points in forcing the downscaling model (large number law), and by choosing these reference points where the AROME's uncertainties are the lowest.

AROME-CFD500 Validation process by an independent expert



Extension to the production assessment for real power plants

With serious calculation of uncertainties, the AROME-CFD method presents a real alternative to physical measurement and P50/P90 production assessments, that may also induce uses in the frame of short term production forecasts.

Conclusions

AROME Mesoscale model provides a first assessment of wind resource over 15 years at 2.5km resolution. To improve reliability, the long-term simulation over the first 10 years includes a 6h surface analysis-cycle and the last five years is taken from operational runs with surface and atmosphere data assimilation.

CFD500 complementary downscaling allows a better representation of complex topography where outputs uncertainties of AROME model, as determined by a Bayesian method, are too high. So that, taking as inputs the CFD500 outputs (themselves driven by AROME ones), the method offers the opportunity to deliver complete P50/P90 wind power plant production assessments in these areas.

This kind of complementary approach, used here in a long-term simulation, can also be applied directly to short term wind power plant production forecast.

References

1- Y. Selly, P. Brousseau, S. Malardet, G. Hello, P. Bénard, F. Boutier, C. Lac, and V. Masson, 2011: The AROME-France Convective-Scale Operational Model. Mon. Wea. Rev., 139, 976-991. doi: http://dx.doi.org/10.1175/2010MWR3425.1
 2- G. Desroziers, L. Berre, V. Chabot, and B. Chapnik, 2009: A Posteriori Diagnostics in an Ensemble of Perturbed Analyses. Mon. Wea. Rev., 137, 3420-3438. doi: http://dx.doi.org/10.1175/2009MWR2778
 3- P.D. Hoff, 2011: A first course in Bayesian statistical methods (Springer)
 4- Venkatesh Duraisamy Jothiprakasham - Centre d'Enseignement et de Recherche en Environnement Atmosphérique - Thesis Downscaling wind energy resource from mesoscale to local scale by nesting and data assimilation with a CFD model - May 2014
 5- Kämpfner, Jens, Bethke, Julia, Mengelkamp, Heinz-Theo, from anemos GmbH, Grötzer, Anselm from CUBE Engineering GmbH, Kläs, Tobias, Pauscher, Lukas, Calles, Doron from Fraunhofer Institut for Wind Energy and Energy System Technology (IWES), Extensive verification of mesoscale and cf500 model downscaling - March 2014