PO.114

Combining National Meteorological meso-scale data modelling and CFD, for wind power plant production assessments

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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

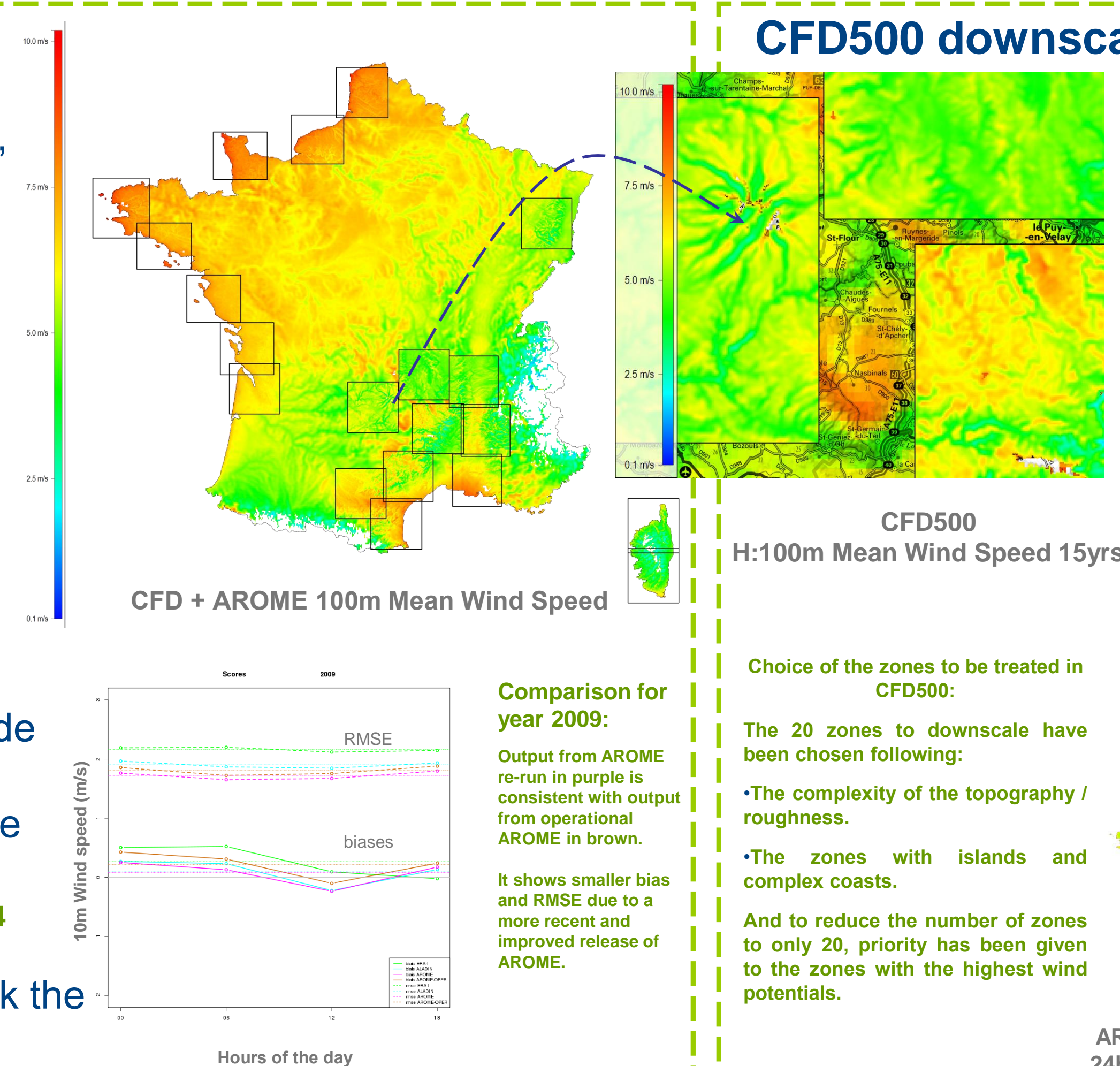**Long-term simulation** 10 years 2000 - 2009

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.

CFD + AROME 100m Mean Wind Speed

CFD500 H:100m Mean Wind Speed 15yrs

Comparison for year 2009:
Output from AROME re-run in purple is consistent with output from operational AROME in brown.
It shows smaller bias and RMSE due to a more recent and improved release of AROME.
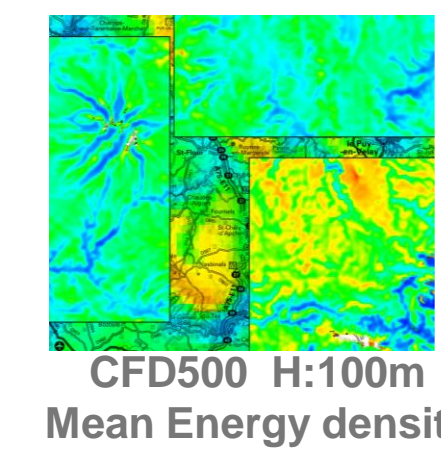
CFD500 downscaling method

This method allows to go from a grid of 2,5kmx2,5km to a grid of 500mx500m. 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)
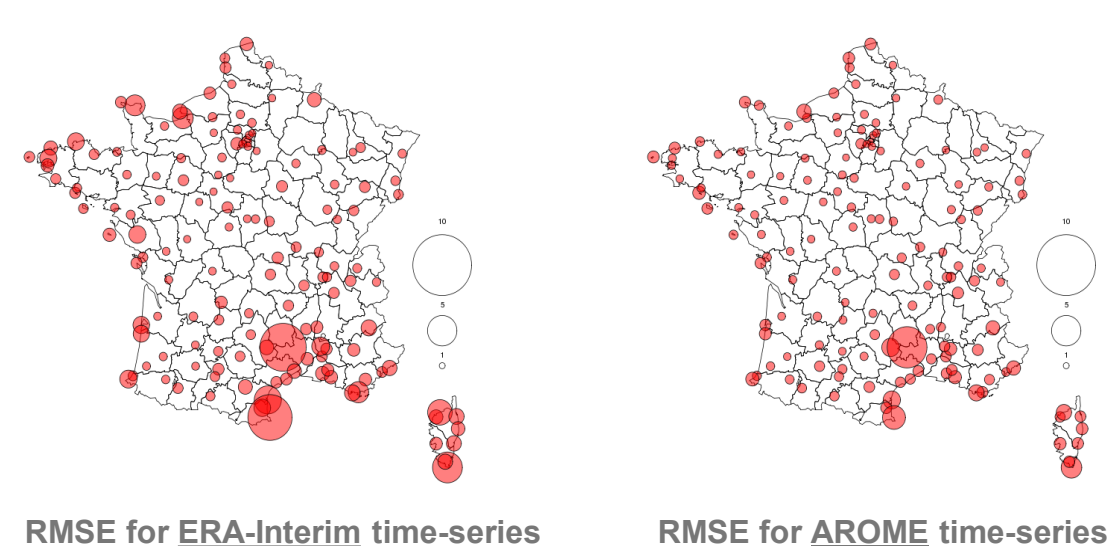
CFD500 H:100m Mean Energy density

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,
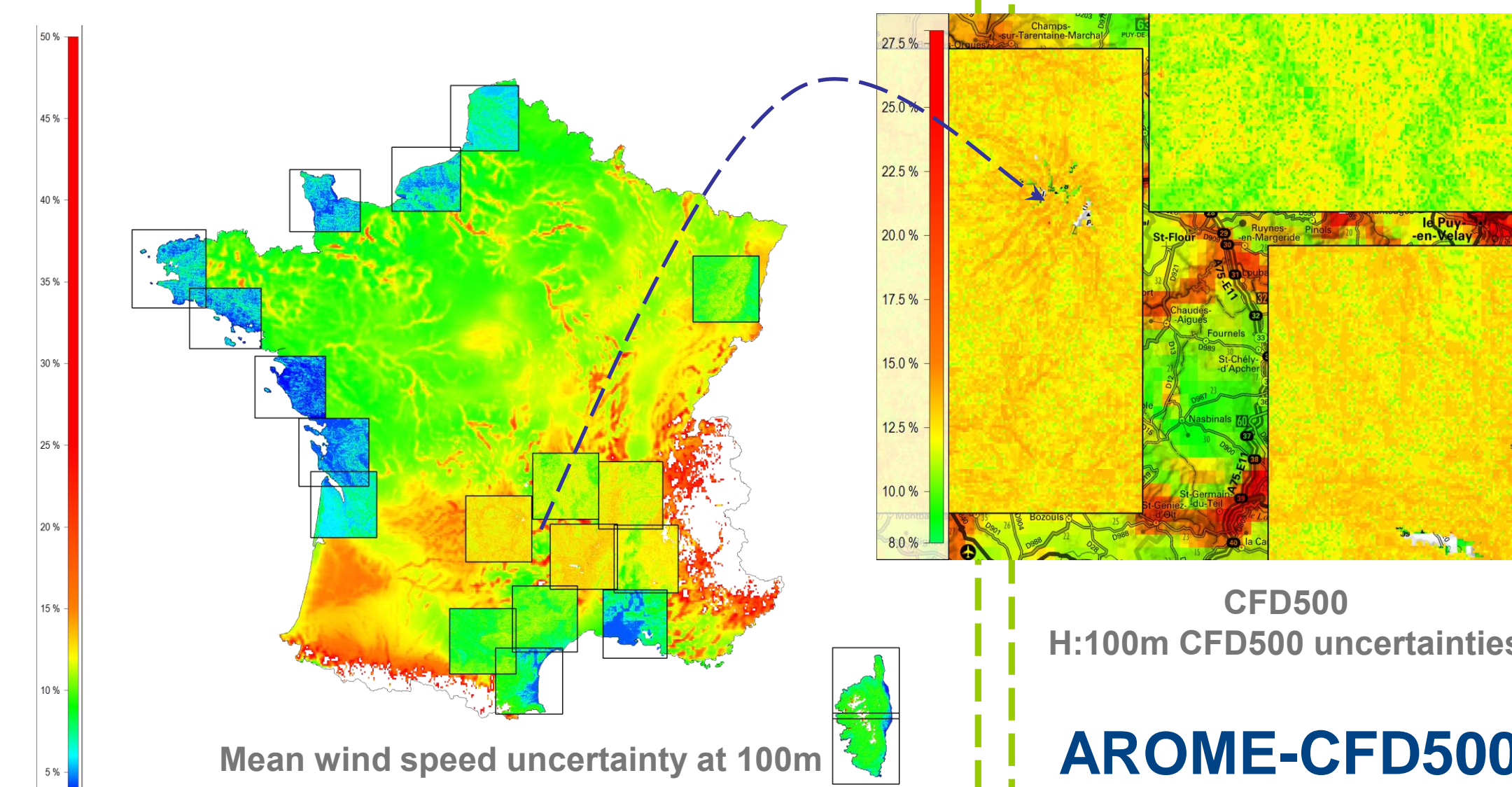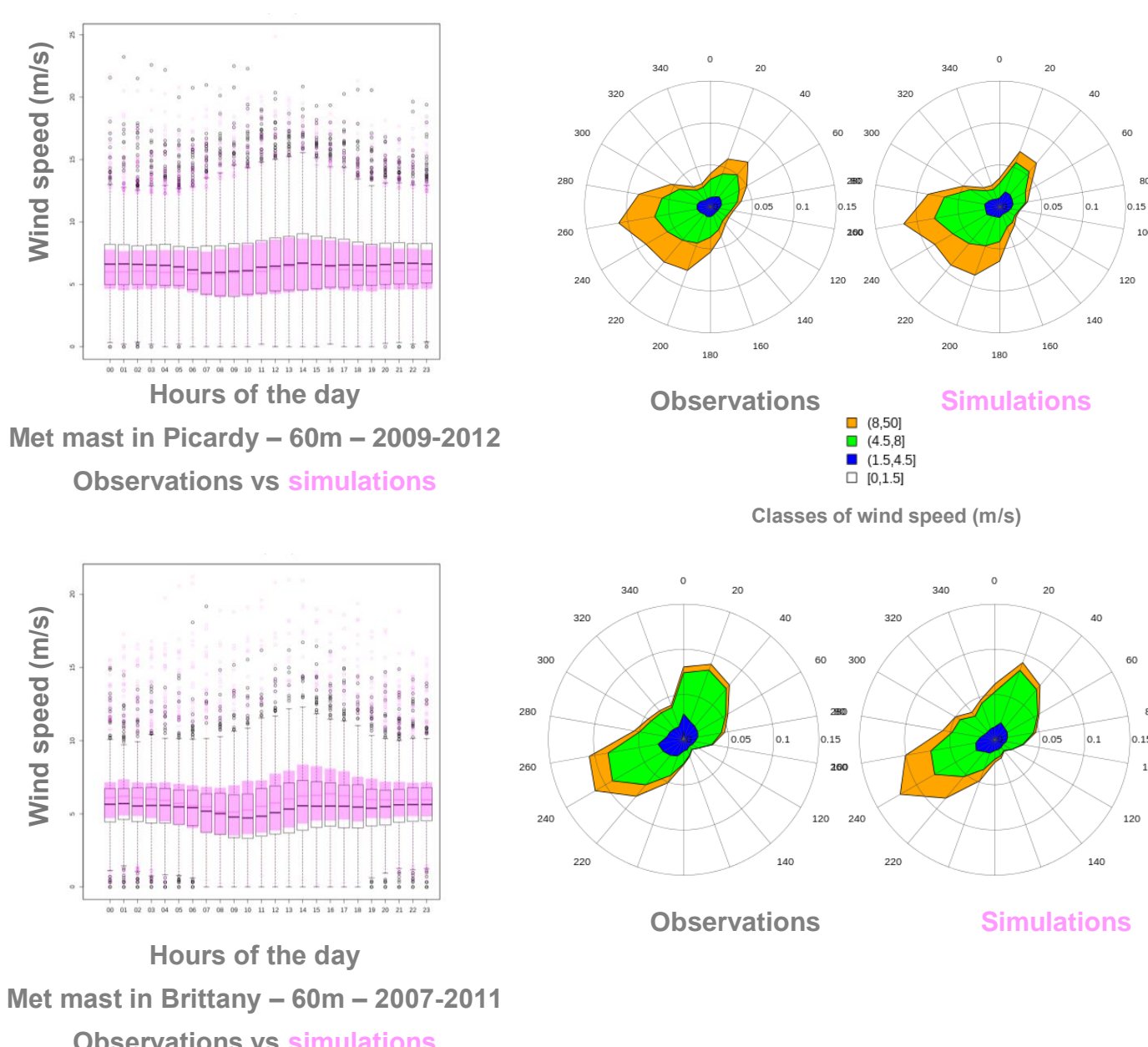- Confidence intervals

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.

AROME + CFD500 H:100m 24h standard deviation map

Verification of AROME simulated time-series

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

Stations where RMSE remains high are mainly located in mountainous areas.
RMSE is reduced, on average, by 0.5 m/s from ERA-Interim to AROME.
Bias is also reduced and close to zero.

RMSE for ERA-Interim time-series

RMSE for AROME time-series

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

Met mast in Picardy – 60m – 2009-2012
Observations vs simulations

Met mast in Brittany – 60m – 2007-2011
Observations vs simulations

AROME shows a strong ability to reproduce daily cycles and local effects such as sea breeze.
To preserve the daily cycle reproduced by AROME, the forecasts are extracted from the same run for 0h to 23h.
Comparisons at 60m height demonstrate this ability to reproduce daily cycle.
Wind directions are also well reproduced.

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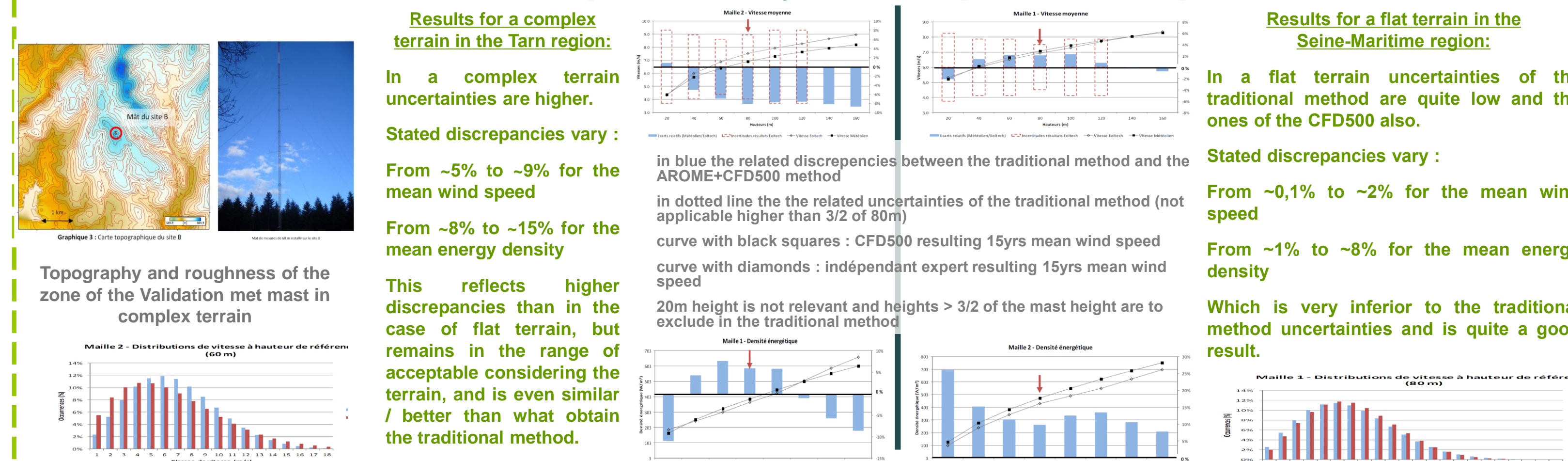
Prior distributions are quantified according to a former ALADIN wind atlas and its known errors in comparison with wind speed observations at 10m height.

CFD500 H:100m CFD500 uncertainties

Mean wind speed uncertainty at 100m

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

Results for a complex terrain in the Tarn region:
In a complex terrain uncertainties are higher.
Stated discrepancies vary :
From ~5% to ~9% for the mean wind speed
From ~8% to ~15% for the mean energy density
This reflects higher discrepancies than in the case of flat terrain, but remains in the range of acceptable considering the terrain, and is even similar / better than what obtain the traditional method.

Topography and roughness of the zone of the Validation met mast in complex terrain

In blue the related discrepancies between the traditional method and the AROME+CFD500 method
in dotted line the the related uncertainties of the traditional method (not applicable higher than 3/2 of 80m)
curve with black squares : CFD500 resulting 15yrs mean wind speed
curve with diamonds : independant expert resulting 15yrs mean wind speed
20m height is not relevant and heights > 3/2 of the mast height are to exclude in the traditional method

Results for a flat terrain in the Seine-Maritime region:
In a flat terrain uncertainties of the traditional method are quite low and the ones of the CFD500 also.
Stated discrepancies vary :
From ~0,1% to ~2% for the mean wind speed
From ~1% to ~8% for the mean energy density
Which is very inferior to the traditional method uncertainties and is quite a good result.

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. Seity, P. Brousseau, S. Malardel, G. Hello, P. Bénard, F. Bouttier, 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, 3420–3436. doi: http://dx.doi.org/10.1175/2009MWR2778
3- P.D. Hoff, 2011: A first course in Bayesian statistical methods (Springer)
4- Venkatesh Duraisamy Jothiprakasam - 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- Kampmeyer, Jens, Bethke, Julia, Mengelkamp, Heinz-Theo, from anemos GmbH. Grötzner, Anselm from CUBE Engineering GmbH. Klaas, Tobias, Pauscher, Lukas, Callies, Doron from Fraunhofer Institut for Wind Energy and Energy System Technology (IWES), Extensive verificaton of mesoscale and cfd- model downscaling- March 2014

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