Climate information for the wind energy industry: a study for the Mediterranean Region

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Introduction and Motivation

During the first phase of EU-FP7 CLIMRUN project, wind speed has been identified as a key climate variable of interest for the case studies on energy that cover the Greater Mediterranean region involving Morocco, Spain and Cyprus. Most of the interest concerning wind modelling focuses on the very short-range (nowcasting) and on seasonal forecasts, because the largest part of the manageable risk is concentrated on these time-scales. However, the interaction with stakeholders, especially in the energy sector, has highlighted the need for more in depth understanding of wind modelling capacities at a longer time scale, which may contribute to both site evaluation in the absence of very accurate wind atlases and on the assessments of risks that may affect the return on investments on longer time scale.

Recent studies have demonstrated that regional climate models (RCMs) have a large potential for enhancing the quality of climate projections in the presence of complex orography (Artale et al 2010) and in the proximity of coastal areas (Winterfeldt J. and R. Weisse, 2009: Winterfeldt et al., 2010; Feser et al. 2011). Under CLIMRUN, we have moved one step forward and started the evaluation of wind modelling in the context of today's largest and most consolidated ensemble of RCMs produced during the EU-FP6 ENSEMBLES RCMs simulations over Euro-Mediterranean region (Fig.1; Christensen et al., 2009).

Data

For the assessment of the ensemble skill have considered the 10-m wind speed from 12 RCMs control simulations, mostly at a horizontal resolution of 25Km, driven by the global reanalysis ERA40 spanning over the time interval 1961-2000. The evaluation of the model ensemble is performed for sea surface wind, for which systematic gridded observation are freely available.

Here, we compare the model ensemble data with the QuikSCAT LEVEL3 observational dataset (Physical Oceanography DAAC, GuideDocument, 2001). This dataset has a global coverage at daily frequency and a horizontal resolution of 0.5° x 0.5°. The comparison with field observation from moored buoys in a few locations in the Mediterranean shows a mean bias error ranging from -.6 to -.6 m/s and a root mean square error ranging from 1.44 to 2.29 m/s (Ruti et al 2007)

The analysis of the climate scenario is conducted by considering the A1B scenarios produced by using the same RCMs analysed for the control period. In this case the ensemble is composed of 16 members, since some of the 12 models evaluated over the control period (HIRAM5,RACMO2,HIRAM) have been driven with multiple global models.

	Model name	ERA40 Simulation	A1B Scenario	A1B Scenario Global driver
1	C4IRCA3	X	X	HadCM3Q16
2	CNRM-RM4.5	X	X	ARPEGE
3	DMI-HIRHAM5	X	X	ARPEGE
4	DMI-HIRHAM5		X	BCM
5	DMI-HIRHAM5		X	ECHAM5-MPIOM r3
6	ETHZ-CLM	X	X	HadCM3Q0
7	ICTP-RegCM3		X	ECHAM5-MPIOM r3
8	INMRCA3	X		
9	KNMI-RACMO2	X	X	ECHAM5-MPIOM r3
10	KNMI-RACMO2		X	MIROC3.2-hires
11	METNOHIRHAM	X	X	BCM
12	METNOHIRHAM		X	HadCM3Q0
13	METO-HC HadRM3Q16	X		
14	METO-HC HadRM3Q3	X		
15	METO-HC HadRM3Q0	X	X	HadCM3Q0
16	MPI-M-REMO	X	X	ECHAM5-MPIOM r3
17	SMHIRCA	X	X	ECHAM5-MPIOM r3
18	SMHIRCA		X	BCM
19	UCLM-PROMES		X	HadCM3Q0

Table1: Regional climate simulations analysed in this study from ENSEMBLES- RCM data portal (http://ensemblesrt3.dmi.dk/).

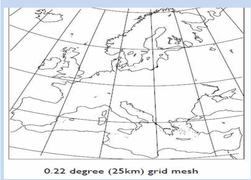

Figure 1. Minimum model domain adopted for the 25km RCM simulation streams over Euro-Mediterranean region during ENSEMBLES. ((http://ensemblesrt3.dmi.dk)

Abstract

According to the World Wind Energy Association the total wind generation capacity worldwide has come close to cover 3% of the world's electricity demand in 2011. Thanks to the enormous resource potential and the relatively low costs of construction and maintenance of wind power plants, the wind energy sector will remain one of the most attractive renewable energy investment options.

Studies reveal that climate variability and change pose a new challenge to the entire renewable energy sector, and in particular for wind energy. Stakeholders in the wind energy sector mainly use, if available, site-specific historical climate information to assess wind resources at a given project site. So far, this is the only source of information that investors (e.g., banks) are keen to accept for decisions concerning the financing of wind energy projects. However, one possible wind energy risk at the seasonal scale is the volatility of earnings from year to year investment. The most significant risk is therefore that not enough units of energy (or megawatt hours) can be generated from the project to capture energy sales to pay down debt in any given quarter or year. On the longer time scale the risk is that a project's energy yields fall short of their estimated levels, resulting in revenues that consistently come in below their projection, over the life of the project.

The nature of the risk exposure determines considerable interest in wind scenarios, as a potential component of both the planning and operational phase of a renewable energy project. Fundamentally, by using climate projections, the assumption of stationary wind regimes can be compared to other scenarios where large scale changes in atmospheric circulation patterns may affect local wind regimes.

*In the framework of **CLIM-RUN** EU FP7 project, climate experts are exploring the potential of seasonal to decadal climate forecast techniques (time-frame 2012-2040) and regional climate scenarios (time horizon 2040+) over the Mediterranean Region as a tool for assessing the impact of changes in climate patterns on the energy output of wind power plants. Subsequently, we will give here a brief overview of these techniques as well as first results related to wind projections for different sites across the Mediterranean Region. We will highlight that regional climate models have a large potential for enhancing the quality of climate projections in the presence of complex orography and in the proximity of coastal areas.*

Validation

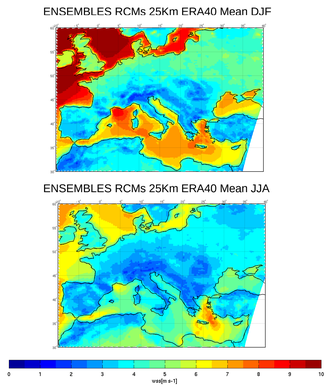

Figure 2 DJF and JJA wind speed ensemble seasonal average for ENSEMBLES RCMs ERA40 simulations.

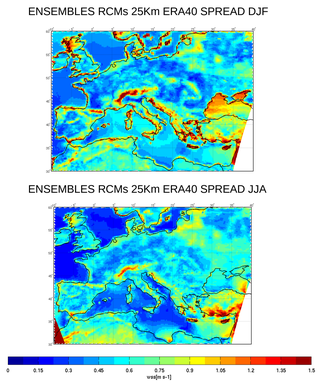

Figure 3 Spread of the ENSEMBLES ERA40 RCMs simulations for the wind speed seasonal average for DJF and JJA

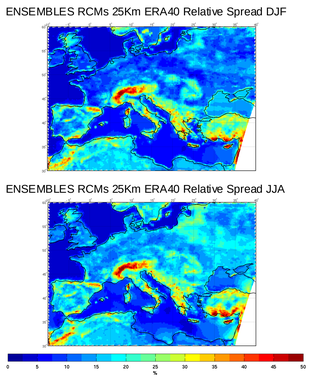

Figure 4 Relative Spread (σ/μ) of the ENSEMBLES ERA40 RCMs simulations for the wind speed seasonal average for DJF and JJA

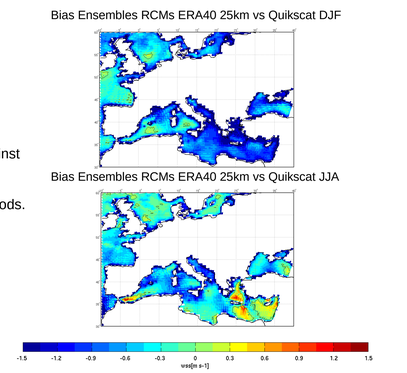

Figure 5 Bias of the ENSEMBLES RCMs ERA40 simulations against QuikSCAT data for the wind speed over sea in winter and summer periods.

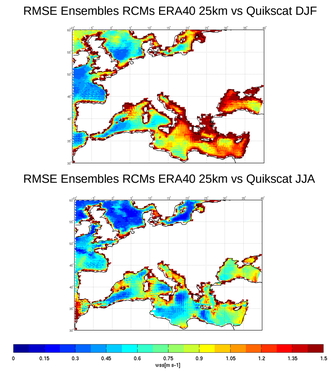

Figure 6 RMSE of the ENSEMBLES RCMs ERA40 simulations against QuikSCAT data for the wind speed over sea in winter and summer periods.

Scenario

After the validation step above described, we have analysed the SRES A1B RCMs ENSEMBLES simulations reported in table1 in terms of future changes of monthly wind speed.

The maps reported in Fig. 6 show the projected changes in 10m wind speed over the Mediterranean. The map is obtained by averaging the winter and summer mean wind speed changes foreseen in ENSEMBLES RCMs scenario for 2021-2050 against 1961-1990. Hatched areas represent areas where more than 66% of simulations agree in the sign of the long term change. According to those projections, most of the Mediterranean region is expected to see a decrease in mean wind speed during winter especially in the southern part of the basin.

It is useful to discuss figure 6 by considering the relative importance of the *ensemble* bias and of the *ensemble* spread in characterizing the uncertainty of climate projections (section 3). During summer the tendency over the Western Mediterranean and over the Ionian sea is relatively weak. However, given the correspondingly small *ensemble* spread (figure 5), a majority of the members of the *ensemble* agree at least in the sign of the tendency. On the other hand, during winter a larger *ensemble* spread is detected over most of the basin (figure 5). However the long term tendency is also relatively large and a weakening of the wind field is a common characteristic of the majority of the *ensemble* members.

The Levantine and the Aegean sea are characterized by both a large bias and a relatively large *ensemble* spread thereby indicating a common difficulty in the modelling of wind regimes in this particular area of the Mediterranean.

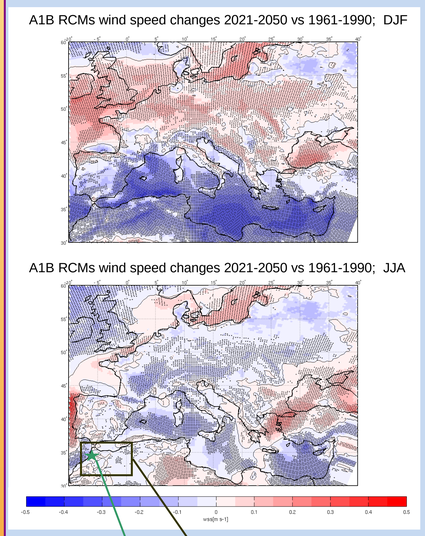

Figure 7: Mean change in surface wind speed projected by A1B scenario RCMs ENSEMBLES simulations. Colours represent the average long term change in wind speed projected for 2021-2050 with respect to 1961-1990. Model data are produced at an horizontal resolution of about 25Km with the exception of KNMI-RACMO2 simulation driven by MIROC that has been produced at 50km . Hatched areas represent areas where more than 66% of the model agree in the sign of the long term change. The solid lines are for zero contour.

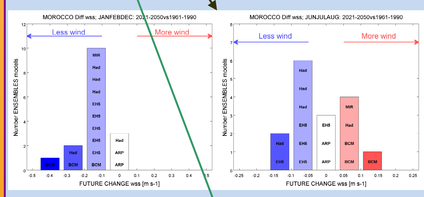

Figure 8 Histogram of A1B RCMs ENSEMBLES simulations (with the corresponding global drivers) for foreseen changes in wind speed over a box (LON:7W-1E; LAT=32-36N) enclosing Morocco. We report the projected changes for 2021-2050 against 1961-1990.

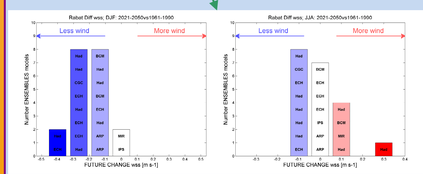

Figure 9 Histogram of A1B RCMs ENSEMBLES simulations (with the corresponding global drivers) for foreseen changes in wind speed over Rabat. We report the projected changes for 2021-2050 against 1961-1990.