Using the MM5 model for wind prediction in a complex terrain site

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Short term prediction models for wind power need meteorological forecastas as input. The better the quality of the available meteorological forecasts the better the wind power prediction that be obtained for on-line operation models.

In Spain, meteorological forecasts are regularly delivered by the National Institute os Meteorology by means of an operational Numerical Weather Prediction System based on the HIRLAM model with a maximum spatial resolution of 0.2º lat x lon. The use of a higher resolution model should produce better meteorological forecasts, and therefore better wind power prediction, particularly on complex terrain sites. Dynamical downscaling technics have been proved as an adequate tool for characterization of regional features linked to complex orography. This technique has already been used by the EPPE (Ente Público Puertos del Estado, Spain), within the HIPOCAS EU-funded proyect, to produce a high resolution 44-year atmospheric database for the Mediterranean basin through the REMO model. A comparison between this data and MM5 on an offshore site is considered a first step in order to obtain a higher resolution database.

The authors have tested the influence of different combinations of parametrizations and nesting strategies for predicting wind on a complex terrain site with MM5 to provide realistic/efficient forecasts adapted to the characteristics of the area and case study.

Introduction

Dynamical downscaling techniques have been proved as an adequate tool for characterizating of regional features linked to complex orography. MM5, the Fifth-Generation NCAP/Penn State Mesoscale Model (Duhdia et al. 2003), is a community model which has desirable features for this task, as nesting strategies, data assimilations for dynamical initialisation and non-hydrostatic dynamics. Also must be taken into account the availability of several optional parametrization configurations for convection, radiative, boundary layer physics as well as other processes, which are of relevance to provide a realistic /efficient forecast adapted to the features of the area and case study.

The authors have considered all those advantages mentioned above for two purpoises. On one hand they have studied the viability of MM5 to build a high resolution meteorological hindcast database. Commonly, hindcasted data (from the NCEP or ECMWF) are the source of information when long time intervals, beginning in the past, are wanted. The resolution of these databases is never greater than 100 Km, which is insufficient when our area of interest may be even smaller, and the meteorological variables may be defined just by one grid point. Therefore, a higher resolution database becomes a necessary tool to achieve a fitted description of the wind behaviour in a certain site, particularly on a complex terrain location. As a first step MM5 output have been compared with the already existing meteorological database hindcasted by the EPPE.

On the other hand the authors have tested the influence of several nesting strategies and combinations of parametrizations in order to carry out an accurate wind forecast in a certain complex terrain location.

REMO and MM5 Comparison

The EPPE has recently hincasted a high resolution 44 year meteorological database for the Mediterranean basin (Sotillo et al 2002). It was developed within the HIPOCAST project trough the REMO (REgional MOdel), which is an hydrostatic model developed in the MPI (Max Planck Institute fuer Meteorologie). Both models, REMO and MM5, differ in their physics. A comparison between the models under similar conditions is important to figure out if a real improvement is obtained.

- Both models were forced with NCEP Global Reanalysis data, archived on a 2.5 x 2.5 degree latitude/longitude grid, with 20 hybrid levels in the vertical for the REMO model and 23 sigma half-levels for the MM5 model.
- The time period simulated ranged from January 1st 1994 at 00 UTC to January 31st 1994 at 18 UTC, and model output was stored every three hours.
- Similar mesh was defined, a 50 Km grid resolution domain containing the whole Mediterranean area (Fig.1)

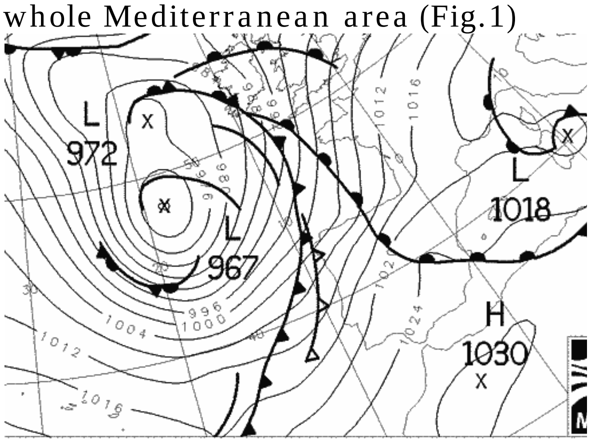


FIG.1 Orography and Land-Sea Mask used in the Integrations

REMO model used a spectral nudging method to keep the model solution close to NCEP reanalysis values at largest scales, while it is free to solve smaller scales. This spectral nudging was applied only to the zonal and latitudinal wind components over the PBL levels. Searching the higher resembrance betwwen the configuration of the models, MM5 was also nudged. The nudging technique added newtonian relaxation terms to the pronostic equations for wind components above the PBL, relaxing the model towards the reanalysis data.

Although our aim was to compare wind predictions, two more variables were selected to make the comparison more reliable: 10 meters wind speed and direction, 2 meters air temperature and sea level pressure were chosen.

As a first approach to the subject, models were compared on an offshore site where observations, from a buoy belonging to the EPPE, were available. However this location characteristics are quite the opposite to complex terrain ones, this initial experiment was necessary to validate both models given the MM5 configuration (parametrizations, nudging, etc) selected.

The chosen buoy is at Mahon (Balear Islands), and its observational data were compared with the respective nearest grid point of the model mesh for MM5 and REMO.

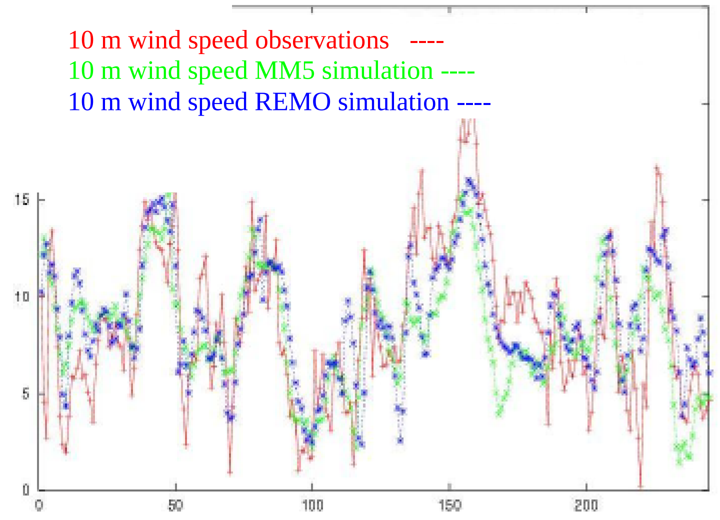
Wind speed	***Correlation***	***RMSE***	***Bias***
MM5	**0.650**	**3.116**	**-0.401**
REMO	**0.697**	**2.896**	**0.233**
MM5 vs REMO	**0.784**	**1.961**	**-0.613**

Table 1. Correlaltion coeffcients for wind speed.

PSLV	***Correlation***	***RMSE***	***Bias***
MM5	**0.983**	**1.253**	**0.962**
REMO	**0.979**	**1.638**	**0.014**
MM5 vs REMO	**0.979**	**1.588**	**0.940**

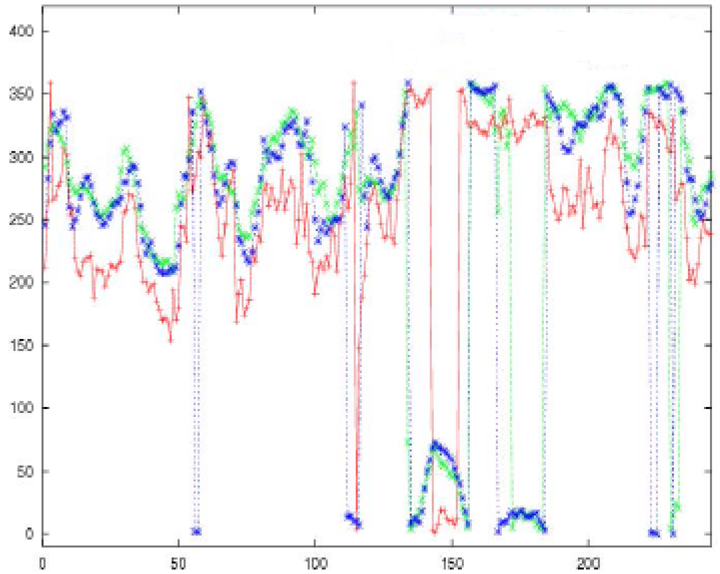
Table 2. Correlation coefficients for Sea Level pressure.

Wind Speed (m/s)



Time (x 3 hours)

Wind Direction (degree)



Time (x 3 hours)

FIG.2 REMO & MM5 wind simulations compared with observations on an offshore site near Mahon Island Fig.2a wind speed & Fig.2b Wind direction

MM5 on a complex terrain site

The goal of this work is to obtain and accurate wind forecast over complex terrain. Nesting strategies and different combinations were tested with measures from a meteorological mast in the Ebro Valley.

MM5 forecasts are performed up to 48 hours and model outputs are stored every hour. A three domain configuration was chosen (Fig.3)

FIG.3 MM5 domain configuration

The spatial resolution of the three domains was 27,9 and 3 km, the outputs were compared with a meteorological station located inside the domain 3.

Two experiments were performed to evaluate the importance of the way of nesting. Firstly a one way nesting is used for D1-D2 and D2-D3 (OWE). Secondly one way nesting is used for D1-D2 and two way nesting for D2-D3 (OTWE).

For creating the initial conditions analysis data (1° x 1° spacial resolution) from the ECMWF were used. The meteorological situation chosen is an unstable situation characterized by a low pressure system located in the North-West of Iberian Peninsula (Fig. 4). In this case strong winds usually blow along the valley.

The first ten minutes of every hour measured values are averaged and compared with the MM5 forecasts. Measures are taken at one point and MM5 output is a grid. For the model the nearest grid point is chosen.

The four domains wind forecasts are quite similar (Figs. 5a-5b). The 9 km domain in one way nesting produce sligthly best results (Table 3). This domain integration needs shorter computing time than the 3km one.

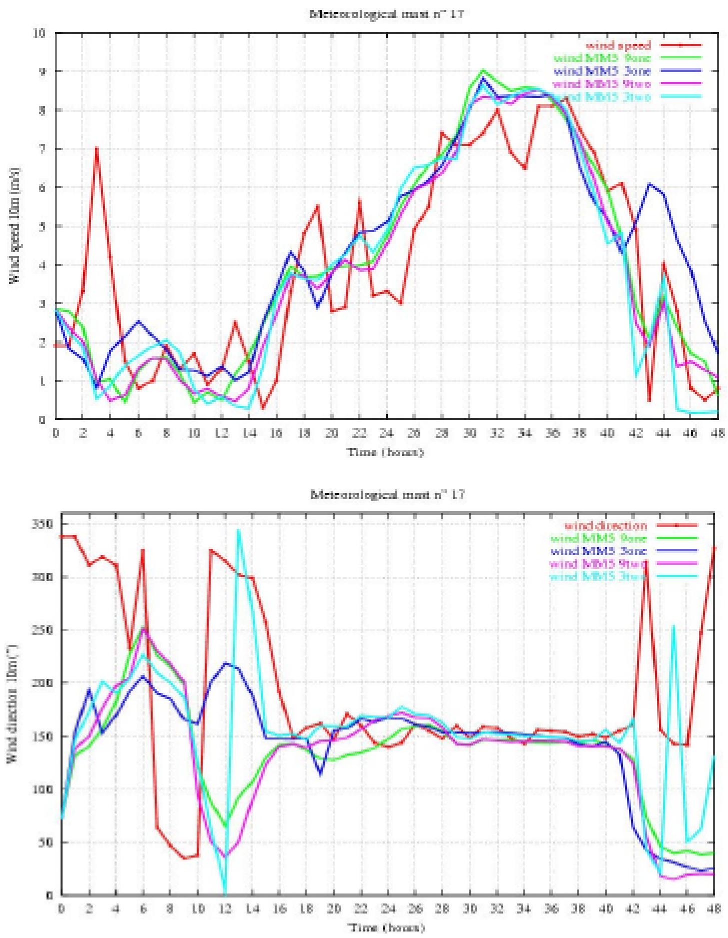
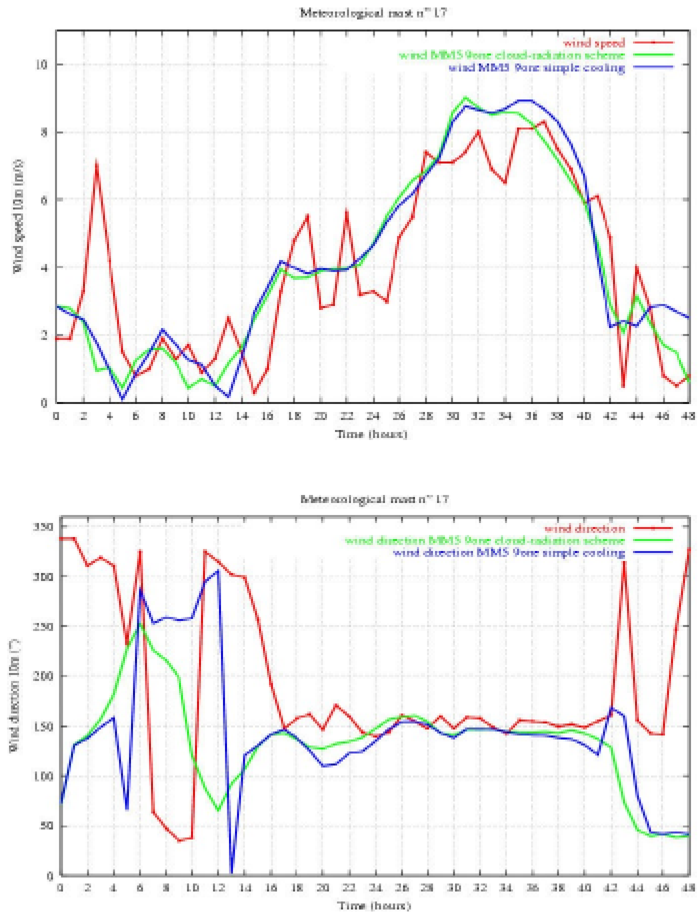


FIG.5a & 5b MM5 multiple nesting forecast using different domain sizes and ways of nesting. Fig.5a wind speed & Fig.5b wind direction

TABLE 3

9one wind speed (m/s)	*Correlation*	*RMSE*	*Bias*
MM5 vs measures	0.82	1.52	0.04

The domain configuration that showed the best result, is selected to change the radiation scheme, in order to compare two different physical options of the MM5 model and in this way to evaluate the importance of changing physical options on final forecast. Simple cooling and cloud-radiation schemes were choosen (Figs.6a-6b)



FIGs.6a &6b . MM5 wind forecast using a different radiation scheme compared with measured data. Fig.6a wind speed & Fig.6b wind direction

There are few differences between the two schemes, as can be seen in figures 6a and 6b. Cloud radiation scheme forecast is slightly closer to measured values.

Conclusions

Both models, wether REMO or MM5, show a very good agreement with observations, and consequently, have quite similar responses. Models agree even when they are not able to follow measured wind.

It is nevertheless true that this verification was necessary to proceed with longer integrations and comparisons on complex terrain sites testing different MM5 configurations. In thoses cases vertical scale becomes very important, so an hydrostatic balance is no longer exact, so more differences are supossed to be obtained. Anyway this has to be done to carry out a final conclusion.

MM5 model is able to make an accurate wind forecast in complex terrain as shown in the figures. Wind speed and direction are quite well forecasted. It seems that it is unneecessary to increase terrain resolution for this specific case, because the results are worser and the computing time higher. However, it would be necessary to do further research into this topic and study the role of the representation of real topography when improving resolution.

References

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