Nesting simulations at two regions on the Iberian Peninsula

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Abstract

The Great Lisbon Area (GLA), Portugal, and Galicia Autonomous Community, Spain, are two regions of the Iberian Peninsula located near the coast, but with a different orientation regarding the dominant synoptic circulation. Both regions have a relative orographic complexity each one with specificity's, i. e.: Galicia has a very gullied coast, where the terrain slope varies enormously, and the GLA has an estuarine zone with some surrounding hills. Taking into account these peculiar terrain features, a model with nesting facility (MEMO model) was applied over these two regions and its response evaluated. Therefore, three domains were chosen for the two regions, with an increasing resolution and a decreasing size.

The wind fields resulting from the simulations were analysed, the influences of the local features on the synoptic pattern were observed and the relative importance of this fact for the two simulated regions was compared. To support this analysis, a study on the terrain slope values for all the simulated domains was performed. The analysis of the results shows that the numerical model has a consistent performance with measured data, and the differences and similarities between the two regions were highlighted.

1 Introduction

The Great Lisbon Area (GLA), Portugal, and Galicia Autonomous Community, Spain, are two regions of the Iberian Peninsula located near
the coast, but with different orientation to some synoptic circulations (figure 1). Both regions have a relative orographic complexity each one with its specificity, i.e., Galicia has a very gullied coast and the GLA has an estuarine zone with some surrounding hills.

Taking into account these peculiar terrain features a model with nesting facility (MEMO model) was applied over these two regions and its response evaluated.

The nesting facility allows the analysis of two flow scales: the influence of the terrain local features, for the small nested domains, and the mesoscale circulations (particularly those concerning sea-breezes circulations) on the large domain simulated [1]. Therefore, three nested domains were chosen for each studying region.

The most important goal of this work was the comparison of the simulated wind fields at both regions and the analysis of the influence of the local terrain features on the development of local circulations. To better understand this analysis, a study on the terrain slope values was done. The MEMO model was applied for the two regions with both non-hydrostaticity and hydrostaticity options.

The meteorological data used at the Lisbon region were based on the LisbEx96 meteorological campaign, designed to better understand the mesoscale circulations over GLA [2]. At Galicia region, model results were compared with measured data obtained in meteorological stations, located within an area of 3600 km$^2$ around As Pontes power plant (ENDESA's property). It was chosen the same day for MEMO application, the 9th of July of 1996, on both regions and the simulations were done for equal periods of time, 24 hours.

2 Regions under study: a brief description

On both regions, the coarse domain was zoomed and nested into two other domains with an increasing resolution. The resolution, and the area of all the three domains, was kept the same on both applications. Namely, 5 km x 5 km for the coarse grid (with an area of 150 km x 150 km), 2 km x 2 km at the medium grid (resulting area of 60 km x 60 km) and, finally, 1 km x 1 km to the fine grid (total area of 30 km x 30 km). The areas of the coarse domains were defined to give the mesoscale conditions to the nested simulations. In following points the most important orographic characteristics of the simulated areas are pointed out.

Galicia Autonomous Community is located on the Northwest of Spain, and is characterised by a very complex orography, with a very gullied coast line, full of Rias (between soft valleys), in the West coast,
Figure 1: Maps of the two regions: Galicia and GLA, with the three simulated domains (CG - Coarse Grid; MG - Medium Grid and FG - Fine Grid)
and deep valleys, in the North coast. On the other hand the GLA have a gently rolling terrain, when compared with Galicia region, as well as mountains with smooth slopes.

3 Synoptic description

To acquire surface meteorological data in the LisbEx96 campaign, several meteorological stations were used, both mobile and fixed, and 4 radiosondes per day were made in Lisbon city. The field campaign took place between the 8th and 17th of July [2].

The chosen day was the 9th of July of 1996 because it appears to better fit the purposes of these study for both regions - simulate the breezes and analyse the influence of terrain features in the wind patterns. To define the initial conditions into the MEMO model, it was applied on the GLA region the radiosondes obtained on the LisbEx96 field campaign, and on the Galicia region the meso-alfa-meteorological prediction in a coarse grid (around 100 km) and 6-hours period, provided by the Spanish Meteorological Office (INM).

On this day, the Azores anticyclone was located at the NW of the Iberian Peninsula with an entrance for SE which had originated a stream from E on the continent and the consequent transport of dry and hot air to the Iberian Peninsula (figure 2). Hence, the meteorological conditions over the GLA and Galicia Region were of clean skies and slow, or moderate, winds, from NE, and moderate winds from NW on the West coast.

Figure 2: Synoptical chart at 12:00 (UTM) (a) at surface and (b) at 500 mbar.

It should be noticed that the coast of GLA and the coast of Galicia region have a different orientation regarding the synoptic pattern (from
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The GLA has a North/South orientation and in Galicia is from West to East.

3 The model

Several applications of the meso-meteorological model MEMO have been undertaken at some European universities. The MEMO model main features are: non-hydrostaticity, prognosis, terrain-following co-ordinates [3], and the possibility of nested runs (on its version 5.0) [4]. In the MEMO Vs 5.0 a one-way interactive nesting scheme is implemented. With this nesting scheme a coarse grid and a fine grid simulation can be nested. During the coarse grid simulation data is interpolated and written to a file. A consecutive fine grid simulation uses this data as lateral boundary values. In the fine grid simulation it was used the expanded radiation condition for the nesting facility, which seems to give more efficient at outflows boundaries [4]. The MEMO Vs 5.0 also allows runs with the hydrostatic approach, which was done during this work.

4 Results

4.1 Slope calculations

The slope calculation is important when one wants to know if the corresponding grid domain, and resolution, is suitable for a computer simulation with the hydrostatic approach. Criteria must exist for this assumption to be applied, and it was found that the application is correct when the slope is less than 15% [5], [6].

In this study, the slope was calculated for all the grid domains of both regions. In the GLA case, the slope in the CG was between 0 and 1%, in the MG less than 5% and in the FG under 7%. Slopes Galicia region are under 9% on the CG, and the values for this variable suffers an increase in the grid domains of finest resolution. As can be seen from figure 3, values between 10 and 15% were obtained for the MG and for the FG the maximum values rounded the 15 and 20%.

A guideline can be taken from these calculations, for the GLA, as well as for the CG in the Galicia region, the hydrostatic approach can be applied because the slope values are in the validity range. Regarding finest domains, MG and FG, of the Galicia region, is better to apply it a meso-meteorological model that integrates the numerical solution of the momentum equation with the term of the non-hydrostatic.
Figure 3: Slope values, in percent, for the Galicia region domains a) CG and b) FG.
4.2 Wind fields

The resulting wind fields for the coarse grid of both domains are represented in figures 4 and 5. It can be observed that for the Galicia region the influence of local features on wind pattern are more important than the mesoscale circulation that may, eventually, be established. In the NE part of the domain exists a mountain near the coast, reaching more than 500 m, that stays perpendicularly oriented to the synoptic wind direction, NE. The wind is forced to surround it and accelerates. This is the reason why sea breeze formation is not very clear.

![Wind field for Galicia region CG - 18 (LST), non-hydrostatic run.](image)

In contrast, a well formed sea breeze entering on land may be seen in the GLA (figure 5), were the mesoscale phenomena seems to play an important role in the influence of synoptic patterns. The wind speed has smaller magnitude values than in the Galicia region, and synoptic wind direction can be noticed in a few parts of the domain, (up and bottom right corners).

Comparison of hydrostatic and non-hydrostatic runs for both fine grids of the two regions can be observed on figures 6 and 7.

Figure 6 shows the difference between the two simulations approach for the GLA. The resulting wind field is stronger on the Tejo estuary in the hydrostatic run than in the non-hydrostatic run. Moreover, the wind speed reaches 6 m s\(^{-1}\) in the simulations for the GLA.
For the Galicia region more intense wind speed was given on the hydrostatic simulation (figure 6 a) and b) than for the GLA region (maximum wind speed values around 9 m s⁻¹).

Comparison between model results and data measurements, gathered at the meteorological station of A Mourela (belonging to the power plant of ENDESA) shows that wind direction suffers a slight rotation that is not represented by the model, both in non-hydrostatic and hydrostatic runs. In what concerns wind speed, the model results exhibit the same trend as the
measured data but the values for this variable are overestimated at all the grid domains (figure 8). The results for the fine grid on non-hydrostatic run gives wind speed values that are closer to the observed data.

Figure 7: Wind field for the fine grid at the Galicia region 18:00 (LST) a) non-hydrostatic, b) hydrostatic run.

Figure 8: Comparison between real data and simulated hydrostatic and non-hydrostatic runs, for the fine grid domain of Galicia region.
5 Conclusions

For the Galicia Region both approaches, hydrostatic and non-hydrostatic, are valid for the coarse and medium grid. Nevertheless, some attention must be paid to the results of the last one. Concerning the fine grid, with 1 km x 1 km resolution, non-hydrostatic approach should be applied, based on the slope criteria and in the comparison between measured and simulated data. Based only on the slope criteria, the MEMO model can be applied to the GLA, both with non-hydrostatic and hydrostatic approaches, for all the grid resolutions. However, in the fine grid simulations the wind field near Lisbon, above the Tejo estuary, are somewhat different, and some careful must be taken on the model application.

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6 References


