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Interactive comment on "The importance of meteorological scales to forecast air pollution scenarios on a complex-terrain coastal site of the Iberian Peninsula" *by* J. L. Palau et al.

J. L. Palau et al.

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The authors would like to thank referee#2 for her/his careful and constructive comments on our manuscript. We also thank the reviewer for his/her positive review of our paper.

The referee had general and specific comments and a few technical corrections, which we now address below.

1. General comment:

The referee expressed no doubts in suggesting the paper to be accepted for publishing in ACP, corroborating the scientific significance of the issues addressed in the paper not only for local to regional climate studies but also for regional weather forecasting, regional climate studies, etc.

We agree with the referee about the objective and the scope of the paper. It is not just a case study, and the main message of the paper is to illustrate the importance of meteorological scales to forecast air pollution scenarios on a complex-terrain coastal site. Thus, following referre#2's suggestion, we'll adopt for our paper the shorter title "The importance of meteorological scales to forecast air pollution scenarios on coastal complex terrain". With respect to the original title, we think it is important to remark that it is a "coastal" complex-terrain because of the synergetic role of the coupling of sea breezes and inland orographic upslope winds into new and stronger thermal circulations when modelling meteorology marked by non-local dynamical effects.

2. Specific comments:

* Referee#2 asked: Are the effects of smaller scale phenomena manifested outside the domains where high-resolution nesting is performed and to what extent?

We consider referee#2's comment a very important and interesting question. As a matter of fact, we have identified influences on the flow pattern within the rest of G2 (downwind of the inner-domain areas); being more marked on the coastal areas and on the mountain tops. Nevertheless, further experiments specifically focused on this eventual effect need to be performed to completely answer this reviewer's comment.

Regarding to the posibility of selecting a limited number of sub-domains to increase resolution only in specific areas, we think that it is rather difficult to apply in complex terrain regions as it is our case. Former studies have shown the importance of grid resolution over the whole Iberian Peninsula on a mesoscale meteorological model simulation (Salvador et al., 1999). A methodology based on a two-dimensional Fourier transform of terrain heights was used to define objectively the grid size required to obtain an adequate representation of a given complex-terrain (two study cases: Iberian Peninsula and the Spanish Mediterranean coast). For the domains studied in the "Spanish Mediterranean coast" case, a grid size of 1.5 km was found to be needed in order to account for 97% of the terrain variance (i.e., as topography is one of the major driving forces of atmospheric dynamics on the Western Mediterranean coasts, at least 3% of the terrain influence on atmospheric flows is lost when simulating the mesoscale dynamic), in contrast to a grid size of 6 km, which would have included 88%, or of 10 km, which would have included 80%.

Note that these results are independent of other effects such as land use, soil moisture, or interaction with other atmospheric processes (as, e.g., the interaction between different meteorological scales).

Obviously, outside the domains where high-resolution two-way nesting is performed there is no information in the model from high-resolution topography; thus, results over these areas can be conditioned by the percentage of terrain variance lost (accordingly to the aforementioned study).

As computer resources are limited, domain configuration must consist in the best way of expend the available power computing resources considering the characteristics of the region of interest. In complex terrain areas, as the Iberian Peninsula where terrain variance suggest the use of grid sizes of 1.5 km, the best option seems to be a domain configuration with the highest resolution extended as much as possible around the area of interest. In our region, meteorological processes interact sinergistically at different scales and it is not possible to identify selected specific areas where increase the spatial resolution to improve the results. However, the procedure that referee#2 suggests probably could be applied in areas where the importance of fine scales is concentrated on specific regions. As a simple example: the vertical injection on isolated mountainous islands located in the ocean could be simulated defining nested domains around the specific islands (allowing uplift of moisture within the fine domain which could be advected within the rest of the coarse domain).

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Reference: Salvador, R., Millan, M. M., and Calbo, J.: Horizontal Grid Size Selection and its influence on Mesoscale Model Simulations. J. App. Met., 38, 1311-1329, 1999.

* Referee#2 commented: It is almost trivial to expect, that similar effects (complex interaction of different scale phenomena) are not unique for the selected region, not even for coastal areas and may take place also in other regions with complex terrain.

Yes, you are right; similar effects are not unique for the selected region (as you previously stated in your general comment, it is not just a case study). Different field campaigns around the globe, e.g., the research projects referred to in the introduction of the paper, have evidenced complex tropospheric structures due to synergetic interactions between topography, synoptic forcings and mesoscale flows.

Nevertheless, it is important to remark that the conjunction of mid-latitudes, complex terrain, and coastal areas reinforces thermal circulations. In complex terrain coastal areas, valley/ridge circulations coupled with sea breezes merge into new and stronger thermal circulations; therefore, secondary or/and compensatory motions can also be more intense than those inland (with similar topographic features).

* Referee#2 asked: Could in this case (under synoptic conditions which do not favour typical mesoscale flow systems described in the paper) small scale phenomena, masked by well organised large scale flows, also have significant influence on the larger scale processes and will a cascade of two-way nested domains provide relevant feedback that will account for this influence in the model simulations?

Yes, definitely.

There are some mesoscale phenomena relevant to air quality studies, which can be present under “prevailing synoptic conditions”, perturbing the “general”, or “synoptic-scale”, flow. Some of these mesoscale perturbations of the general flow (not associated directly with solar heating) have already been documented in different field campaigns:

a) Convective barriers: If a cold air mass comes onto a coastal area and the SST is higher than the cold air coming from inland, the convective barrier formed on the coast can reinforce stagnation episodes on a coastal conurbation.

b) Wind directional shear: Synoptic flows over complex terrain can present strong vertical wind shear in the lower troposphere; in such cases, impacts on the ground due to mechanical turbulence can be produced kilometers away from the "mean transport direction" of the pollutants aloft (i.e., "mean synoptic flow").

c) Mechanical instabilities. Synoptic flows over complex terrain can be perturbed by trapped leewaves (developed leeward of mountain barriers). This mesoscale feature is favoured by the vertical increase of wind speed (i.e., wind shear). Within the context of complex-terrain air-quality simulations under winter conditions, fumigations on the ground leeward of the mountains are one of the most relevant features of the dispersion model results, and these will strongly depend on the meteorological fields resolved by the mesoscale model.

d) Channelisation and stagnation. Topography highly channelises the general flow in the atmospheric layers where most anthropogenic emissions take place. Valley inversions and channelling flows are features that need to be simulated using high-resolution meshes.

All the aforementioned mesoscale features govern the temporal evolution of the air quality under "stable" atmospheres and cannot be forecasted obviating meteorological scales smaller than the synoptic processes.

Referee#2 wonders if two-way nested domains provide relevant feedback that will account for mesoscale influence on the larger scale processes in the model simulations. Recently some of the authors have submitted to the ACP special issue "Urban Meteorology and Atmospheric Pollution (EMS-FUMAPEX)", another paper directly related to this issue and entitled "A study of the dispersion of a power plant plume on complex terrain under winter conditions using high-resolution mesoscale and Lagrangian

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particle models". We think it can be of interest for referee#2.

* About referee#2's last specific comment:

Thank you very much for the reviewer's last "philosophical comment", and I hope the rest of the scientific community will license us to give him/her also a "philosophical answer".

Truly, the expression "(in)adequate scale" is debatable if there is no consensus on what are the "key" meteorological processes to be considered when studying any particular atmospheric feature.

We agree with referee#2 that the highest resolution is not a guarantee for performing the most "adequate" meteorological simulation (especially if, "a priori", one does not establish what meteorological processes are to be simulated).

To our knowledge, grid nesting, domain configuration, and horizontal and vertical resolution are some of the key "model aspects" that must be set up properly to simulate the meteorology using mesoscale models; nevertheless they are not the only, nor even the most important, ones. There is no general and concise "rule" for simulating the atmosphere adequately with (and limited by) the available technology, but rather a "rule of thumb".

When studying a mesometeorological feature, the previous case-by-case "traditional" meteorological analysis is an advantage for performing "a posteriori" realistic mesometeorological simulations. From our point of view, experience and knowledge of the main meteorological processes is a requirement for the necessary "regionalisation" of a generic mesoscale model to the particularities of the region under study.

Of course, there are some literature-settling general rules for an optimum design of modelling exercises or requirements for reducing uncertainties in the meteorological simulations. But, from our point of view, the modeller's expertise always underlies the end product: the knowledge of the relevant physical processes to be simulated and the

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assumption of the physical approximations limiting the parameterisation used within the model when simulating those relevant physical processes.

Thus, when performing a simulation, the definition of “inadequate” or “adequate” scale should be defined (and never obviated) case by case by the modeller or/and researcher from their own “know-how”. That’s what makes the difference, not just the computing power.

3. Technical corrections:

Referee#2 is right; there is a misprint in the text describing table 2. The last sentence must begin as “Simulation S22 was performed...”.

Interactive comment on Atmos. Chem. Phys. Discuss., 5, 4701, 2005.

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