High versus Variable Resolution in Climate Modelling

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The ARPEGE/IFS-based climate model in use at Météo-France for about 10 years (Déqué et al., 1994) has a regional version centered over the Mediterranean basin. This version is a spectral global model with variable resolution based on Courtier and Geleyn (1988). Variable resolution over the globe is an alternative to limited area modelling. It demands more to the computer, since about 50% of the calculations are made outside the area of interest, and less to people in charge of the simulation, since the handling of lateral boundary conditions is avoided. Two possible drawbacks arise from this approach. The first one is the impact of variable mesh on the discretization. This drawback is harmless because two neighbouring grid points have a very similar grid spacing, and the error due to the not exact centering of finite differences is negligible compared with the discretization error. The latitude-longitude discretization of most GCMs induces a larger variability in the mesh size as latitude increases. Moreover, when a GCM uses a spectral resolution, this problem disappears. The second drawback is more serious. It is well known that model systematic errors are resolution dependent. There is a risk that systematic errors in the low-resolution part of the globe contaminate the domain of interest. It is even possible that an imbalance between two regions creates an artificial circulation, resulting in a variable resolution model climate poorer than the low resolution model climate.

The variable resolution approach has thus been extensively tested. First tests with an adiabatic formulation have been followed by tests in long climate runs with variable resolution (Déqué and Piedelievre, 1995). It has been demonstrated that at constant computational cost, a variable resolution model over Europe performs better than a constant resolution one. Recently, Lorant and Royer (2001) extented this conclusion to the equatorial domain, using an aquaplanet version of the model.

The capacity of the last generation of computer have made possible the ultimate test, i.e. the comparison of a variable resolution version, with a version with the maximum resolution over the globe. Our variable resolution model has a maximum resolution of 0.5° in the Mediterranean sea, and a minimum resolution of 4.5° in the south Pacific. The challenger version has a 0.5° resolution over the globe. Its cost is 16 times the cost of the variable resolution version in computation time, since the time step must be halved for numerical stability. The memory and storage costs are 9 times that of the variable resolution model. Of course, if one is interested in other regions like the tropics, the high resolution model offers additional advantages versus the « Mediterranean » model.

Both high and variable resolution models have been run 10 years with climatological sea surface temperatures. In these simulations both models use the same time step (15 min) to ensure a clean comparison. A third simulation of the same kind has been performed with the standard version of the climate model (2.8° resolution). The question is whether the variable resolution (VR) produces a climate closer to the high resolution (HR) than the low resolution (LR) in the Mediterranean area. We limit here our analysis to winter (DJF) and summer (JJA) and to 2 m-temperature and precipitation fields. To avoid a trivial result for temperature, this field is corrected from the orography effect with a 6.5 K/km vertical gradient. Indeed VR has a good representation of orography in the high resolution area.

Figure 1 shows the spatial correlation between VR and HR and between LR and HR for winter precipitation and elevation-corrected temperature as a function of the distance from the pole of resolution. As far as temperature is concerned, the correspondance is very good, due to the pole-to-equator temperature gradient. Beyond 4000 km, VR and LR are equally correlated to HR. As far as precipitation is concerned, the correlation is smaller, but VR is a better approximation to HR than LR in the high resolution area.

Figure 2 presents the same parameters for summer. The main difference with winter is in the higher variability of the precipitation correlation as a function of distance. At about 3000 km from the center of the Mediterranean sea, VR exhibits a minimum correlation, due to the differences in precipitation pattern in tropical Africa. Nevertheless, VR is still the better simulator of HR in the high resolution area.

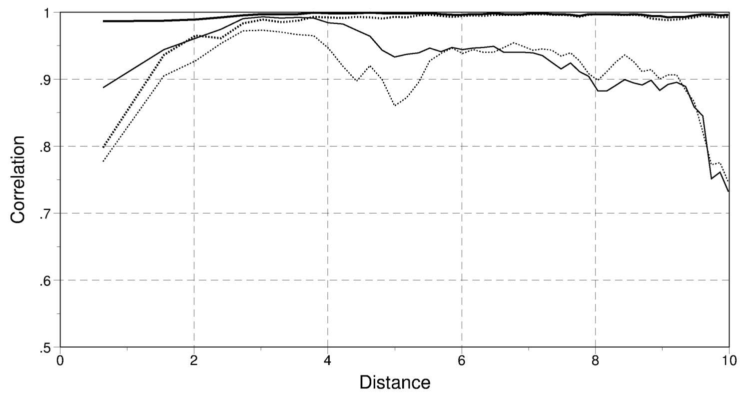

Figure 1: correlation between variable and high resolution (solid line) and between low and high resolution (dot line) as a function of the distance from the center of the Mediterranean sea (unit 1000 km) for precipitation (thin line) and temperature (thick line) in DJF.

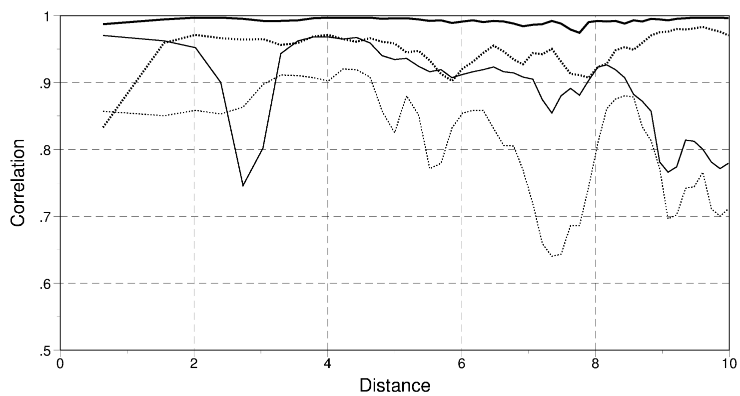

Figure 2: as Figure 1 for JJA.

References

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