A big brother multi-pole experiment with stretched grid GCMs

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Limited domain and global variable resolution models are the two cheap techniques to produce a full dynamical climate simulation at high resolution. Each technique has its advantages and drawbacks. Although limited domain models (e.g. Giorgi 1990) are always based on a rectangular domain surrounded by thin rectangular relaxation areas, there exist several techniques to produce variable resolution over the globe (Fox-Rabinowitz et al., 2008). As demonstrated by Courtier and Geleyn (1988), the only method which ensures isotropy everywhere is the one based on homothetic expansion on a stereographic projection plane. Isotropy of the horizontal discretization is a useful property because the atmosphere equations (except the Coriolis term) are independent of the direction of the axes. So, introducing anisotropy in the numerics introduces artifacts in the solutions, e.g. by filtering more waves coming from the West than waves coming from the North. On the other hand this technique is little flexible with regard to the domain definition. Indeed, as soon as the pole of high resolution and the total number of points are defined, the only degree of freedom is the stretching factor: with a high stretching factor, you get high resolution near the pole, but the resolution decreases rapidly when going to the antipodes. It is not possible to combine high resolution over a wide area and low resolution over the rest of the globe, with a reasonable transition in between.

In Déqué (2010) two experiments are presented in a "perfect model" framework. A high resolution global GCM is supposed to be a reference that several stretched-grid GCMs try to mimic. In the first experiment, the GCMs are run without constraint. One observes that the statistical characteristics are tiling rather nicely: the grid points can be pooled so that the different stretched runs produce a quasi-seamless distribution over the globe. However, when a single day is considered, the "GCM-mosaic" is no longer seamless, because each stretched simulation is independent. In a second experiment, the stretched GCMs are driven by a low resolution GCM in the part of their grid where resolution is low. Then, as can be seen for example by Hovmoeller diagrams, the "GCM-mosaic" is almost seamless on a day-to-day basis. The added value of the "mozaic GCM" with respect to the low resolution driving GCM can be evaluated by comparing to the high resolution GCM. However, this comparison can be done only in terms of statistical distribution, because the chronology of the high and low resolution runs are independent.

In order to evaluate the ability of the re-created high resolution to mimic the reference, the big brother approach (Denis et al., 2002) is a traditional approach in regional climate modeling. This is the aim of the present study. Here the big brother is a TL511 (40 km mesh) version of ARPEGE-Climate version 5.1 (Déqué 2010). A 20-year simulation with monthly observed SSTs (1989-2008) is performed, and the 6-hourly prognostic variables are filtered to TL127. This big brother has five little brothers in TL127 (160 km mesh) with a stretching factor of 4, so that the maximum resolution of each little brother is equal to the resolution of the big brother. The five poles are located in the Atlantic-Europe domain, so that the resolution is almost constant: (69.5W,35.5N), (45W,35.3N), (26.2W,49.7N), (0W,40.8N), (26.2E,49.7N).

Figure 1 shows the resolution of the mosaic based on the 5 stretched grids. The dots correspond to the grid points where a given little brother is not relaxed towards the big brother. Thus the dotted area is the equivalent free area of a limited area model. The relaxation time depends on resolution: it decreases from 1 day (resolution 70 km) to 1 time step where the resolution of the little brother is equal to the resolution of the driving conditions (160 km). The driving is much more progressive than in a limited area model, reducing the risk of numerical shock at the boundaries.

Figure 2 shows the DJF mean and standard deviation of mean sea level pressure of the high resolution GCM and the 5 stretched GCMs driven by the filtered output of the high resolution GCM. They are really similar and the seams (guessed from Fig. 1) are hardly visible. The daily correlation between the two models is 0.99. If we apply to the daily fields the same filtering as for the driving conditions to extract the high resolution part, we still have an anomaly correlation of 0.26 in the free zone (dotted area of Fig. 1) between little and big brothers. This shows that the small scales regenerated by the little brothers contain a part of information common with the big brother's small scales.

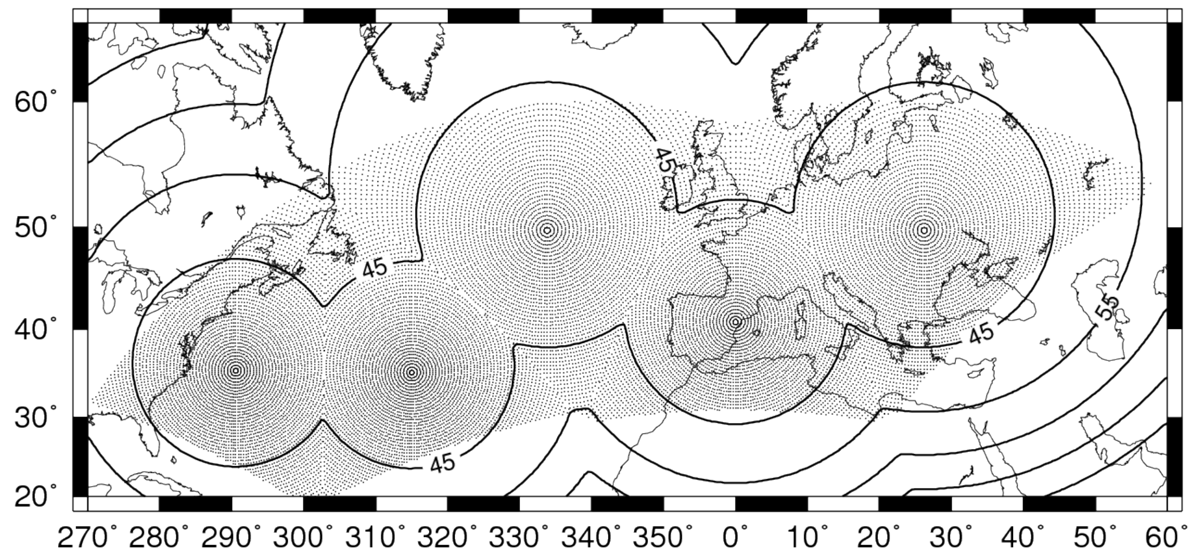

Figure 1: Equivalent resolution of the mosaic obtained with the 5 little brothers (contour interval 10 km); the dots correspond to individual grid points which are not relaxed in the stretched GCMs.

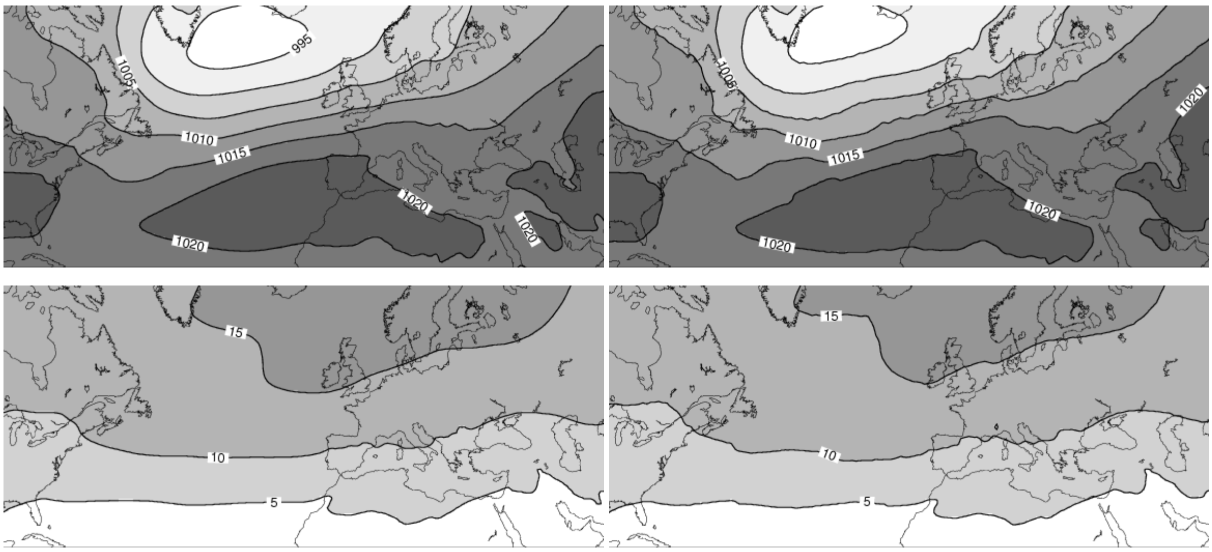

Figure 2: DJF mean sea level pressure of big brother (left) and mosaic of little brothers (right); mean (top) and standard deviation (bottom); contour interval 5 hPa.

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