Variable resolution versus limited area modelling: perfect model approach

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Whatever the power of computer available, climate modellers will find it insufficient to fulfill their needs in horizontal resolution in regional modelling. Two solutions are offered to make model less costly in computer time and core memory. The most widespread is nested modelling. It consists of using a low resolution global model to provide lateral boundary conditions to a limited area model (Denis et al., 2002). The alternative approach consists of keeping a global model, but with high resolution in a part of the globe and lower resolution elsewhere. Different numerical techniques can be used to this purpose. The Stretched Grid Model Intercomparison Project (SGMIP, Fox-Rabinowitz et al., 2005) presents and validates the different techniques.

The ARPEGE/IFS numerical core used at Météo-France and ECMWF proposes the two approaches in the same executable file. Indeed ALADIN is a special configuration of the model in which the sphere is replaced by a torus: in a part of the domain (one x- and one y-zonal band), no physical calculation is done but a smooth interpolation along the two directions is performed; on both sides of these two zones, the prognostic variables of the model are relaxed toward imposed lateral conditions. This method, first proposed by Haugen and Machenhauer (1993), allows to mimic the behaviour of a limited area grid point model with the same dynamics and physics as the driving model with a very competitive cost (only 27 rows in both x- and y-directions are not used for free atmospheric calculations). On the other hand, ARPEGE/IFS can be used with a stretched grid over the sphere: this is done daily in operational forecast, and has been used in climate modelling since Déqué and Piedelievre (1995).

In ARPEGE/IFS the two approaches compliment each other: ALADIN provides a further zoom in the stretched area of ARPEGE. In the present study, we want to compare the two approaches, so ARPEGE is constrained by the same data as ALADIN. This is why a grid point relaxation is introduced in ARPEGE outside the area where ALADIN is free to evolve. Figure 1 shows the free grid points in the two models in a configuration over Europe at 50 km resolution. Because of the projection techniques (stereographic for ARPEGE, Lambert for ALADIN) the two grids cannot exactly match.

If we want to be as model-independent as possible, the perfect model approach is preferable, as the only ingredient that produces the responses we will analyze is the change in geometry. We have thus produced, as forcing and verification data a global simulation with a uniform 0.5° grid (TL359) version of ARPEGE. This simulation uses monthly observed SST from 1979 through 2003.

From this simulation (named S0) 6-hourly data of the model variables are interpolated on both regional grids (stretched and limited area) and saved. Two additional simulations with ALADIN (named S1) and with ARPEGE in stretched geometry (TL159 stretching factor 2.5, named S2). Except the location of the grid points, all parameters are identical in the 3 simulations (time step, vertical levels, physics) or as far as possible (surface characteristics, horizontal diffusion). S1 and S2 also differ in the way the forcing is applied. In S1 model variables are exactly imposed at the boundary of the forcing zone, whereas the constraint is looser in S2 (6h relaxation for wind, 12h for temperature and surface pressure).

The results are analyzed for five variables (2m daily minimum and maximum temperature, 500 hPa height, mean sea-level pressure and precipitation) and two seasons. We compare the ability to reproduce the mean climate by root mean square differences (rmsd) S1-S0 and S2-S0 over a European domain (see figure 1) and the ability to reproduce the chronology of synoptic events by anomaly correlation coefficients (acc) S1 vs S0 and S2 vs S0 over the same domain. Table 1 shows rmsd and acc for the five fields on the domain. Calculation of rmsd is based on 25-year mean seasonal averages, whereas acc is based on daily values (6-hourly values for mslp and z500). One can see that the methods are comparable in winter. In summer, the stretched global model has a smaller temperature bias and a larger precipitation correlation.

References:

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		DJF					JJA				
		tn	tx	z500	mslp	prec	tn	tx	z500	mslp	prec
rmsd	S1-S0	0.7	0.5	8.6	0.7	0.4	1.0	1.4	21.3	0.5	0.5
	S2-S0	0.8	0.6	1.9	0.2	0.4	0.7	0.7	1.6	0.2	0.3
acc	S1:S0	0.86	0.90	0.97	0.97	0.76	0.62	0.71	0.90	0.90	0.38
	S2:S0	0.85	0.88	0.97	0.97	0.76	0.71	0.79	0.94	0.92	0.48

Table 1: Comparison of rmsd and acc for the limited area (S1) and the stretched (S2) models versus the high resolution model in winter and summer: daily minimum temperature (tn, K), maximum temperature (tx, K), 500 hPa height (z500,m) mean sea level pressure (mslp, hPa) and precipitation (mm/day).

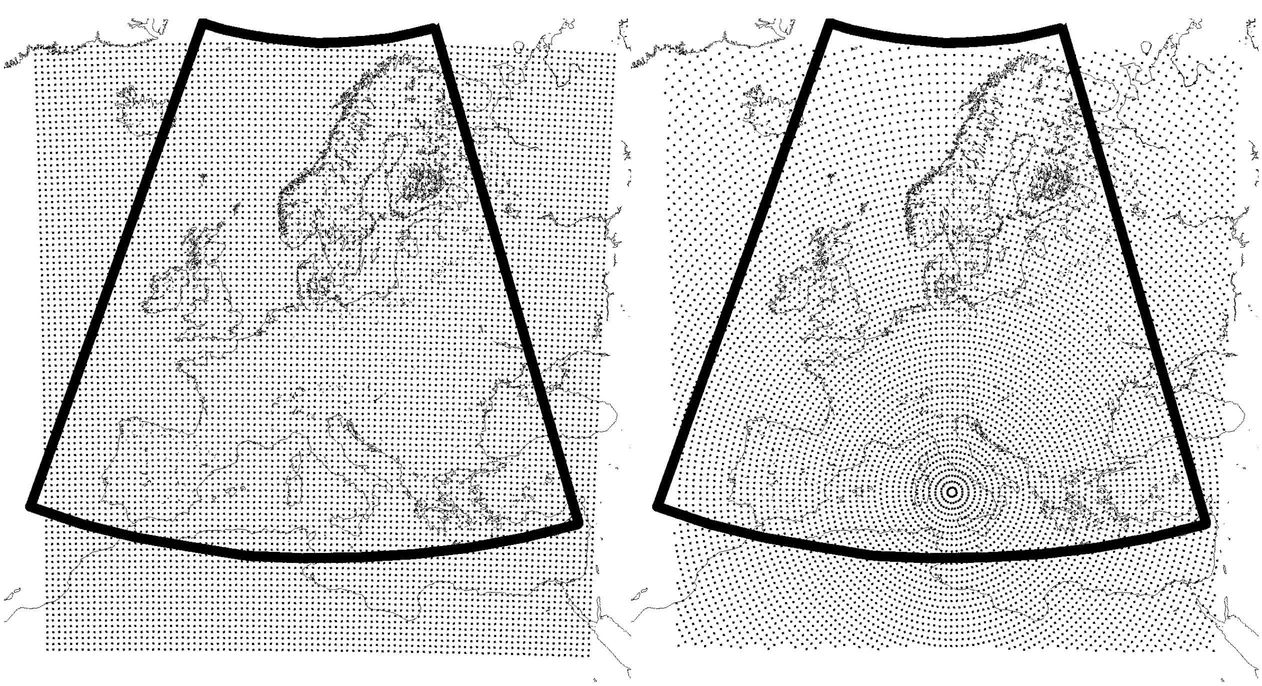

Figure 1: Grid points of ALADIN (left) and free part of ARPEGE (right); lat-lon domain of comparison