Raluca RADU defended her thesis:

Contributions to the study of the coupling problem between limited area models and large scale models

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raluca.radu@meteoromania.ro

Summary

Limited area models (LAM) need the information about the state of the atmosphere outside of the integration domain. This information is provided by global or larger-scale models, so that an inherent LAM problem is the specification of appropriate lateral boundary conditions (LBC). Previous studies have shown that the way LBC are imposed can have a significative impact on the forecasted fields by propagation of errors inside the LAM domain (Warner et al, 1997), mainly due to the following limitations: the overspecification and the weak spatial or temporal resolution of the coupling data. This motivates the objective of this research which has been focused on an in-depth study of the coupling problem for limited area models in order to improve the LBC specification.

In the vast majority of operational limited area models LBC are imposed via a pragmatic coupling scheme, named 'flow relaxation scheme' (Davies, 1983). In this scheme the prognostic variables are subjected to a forcing in the boundary zone that constraints them to relax towards the externally specified field. The Davies coupling is satisfactory if : a) transmits incoming waves from the model providing boundary information without appreciable change of phase or amplitude and b) at the outflow boundaries, reflected waves do not reenter the domain of interest with appreciable amplitude. This method has proved to be detrimental in the case of large-scale fast propagating systems as Lothar storm in Western Europe (25-26 December 1999). At that time some of the European operational models (ALADIN included) failed to forecast the cyclone even if the global models which provided the LBC (ARPEGE model for ALADIN) were able to forecast the event.

We have proposed a spectral one-way coupling method for ALADIN, in which the large scale components of the global model are combined with the small scale components of LAM using scale separation in wavenumber space, in order to minimize the differences appeared in the large scale portion of the coupled models. The spectral coupling/nudging

method has been used in the past as a simple data assimilation method (Davies and Turner, 1977; Schraff, 1997), and in regional climate models as a method to avoid the deviation of large scales of the regional model from the fields provided by the global models (Kida et al, 1991; Waldron et al, 1996; von Storch et al., 2000).

The method had been applied and tested in different versions of the ALADIN limited area spectral model: forecast model (ALADIN), non-hydrostatic model (ALADIN-NH) and regional climate model (ALADIN-CLIMATE). Tests have been carried out at various spatial resolutions (10 km, 3,5 km and 50 km) in short and long-range integrations. The proposed method has also been tested in an idealized framework of the 1D shallow-water model, in selected case studies at high-resolution and in a perfect model approach (global and regional climate model results were compared at the same spatial resolution).

The potential advantages of the proposed method lie in the direct selectivity of the coupling scales, better consistency between the large scale forcing and the fields of the coupled LAM, capability to retain large-scale information independently of the location inside of the integration domain, ease of implementation in spectral models. The superiority of spectral coupling method has been demonstrated both in case studies whereby fast propagating cyclones present in the global model are shown to be seamlessly propagated inside LAM boundaries and in a statistical sense through the computation of errors statistics versus observations when the method was applied in an operational framework (Table 1). When the method was tested at high spatial resolution (3,5 km) on a severe convection event (Movilita, 07.05.2005), the results have indicated the possibility of future application in extreme weather situations developed through scales interaction.

Another aim of the research was to prove one of the objectives of the regional climate modeling: the regional climate models are able to maintain the large scale circulation of the global model by modifying only the small scales. In this respect, the spectral nudging, a dynamical downscaling method, has been used as a suitable approach to force the regional climate model (ALADIN-CLIMATE) to adopt prescribed large scales over the entire domain, not just at the lateral boundaries, while developing realistic detailed regional features consistent with the large scales. The aim of this part of the study was to compare a global spectral climate model at high resolution (50 km) and a driven spectral regional climate model over Europe by using the so-called perfect model approach. The spectral nudging method was applied in order to achieve a better representation of large-scale climate over a limited domain. It was proved in long-term simulations (12 and 25 years) the potential and the feasability of the proposed method seen as solution to overcome the limitations of LBC specification. The results showed that the regional model driven only at its lateral boundaries presented a summer warm bias in the middle of the domain. This bias disappeared when spectral nudging was applied. On the other hand, the smallest scales which were not driven by the spectral nudging were not significantly

	BIAS (24h)	RMSE (24h)	BIAS (48h)	RMSE (48h)
MSLP OP/**SP**	-0,92/**-0,72**	1,43/**1,26**	-0,80/**-0,53**	1,62/**1,44**
2M T OP/**SP**	-0,37/**-0,22**	2,00/**1,95**	-0,54/**-0,40**	2,14/**2,08**

Table 1: Statistics computed for 24h and 48h for MSLP and 2m T forecasted fields with ALADIN model using Davies coupling (OP) and spectral coupling (SP, in bold).

affected by scale interaction. The only detrimental impact of spectral nudging was a slight precipitation increase in the upper quantiles of precipitation, which was resolved by large-scale nudging of specific humidity. It was pointed out that spectral nudging method is able to avoid the deviation of the RCM from the GCM in the spatial scales typical of the GCM (wave length of 600 km and above). This is true for the mean climate (stationary part) as well as for the day-to-day variability (transient part). As far as the smallest scales are concerned, we found very little predictability in the meteorological sense (so called butterfly effect). However, the statistical properties of these small scales (predictability in climatic sense) are not degraded by the effect of relaxation of the lower part of the spectrum.

It was studied the question whether the simulated extreme precipitation in summer and winter with the RCM spectrally nudged show similar characteristics with those simulated in the GCM. For each grid point of the analysis domain, the percentiles of daily precipitation in both seasons have been computed. We have concluded that spectral nudging improves the regional simulation by allowing more intense precipitation events.

The results from regional climate simulations using spectral nudging technique were published in *Tellus A* (Radu et al., 2008 and Colin et al., 2010).

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