Extensive study of the coupling problem for a high resolution limited area model

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1 Introduction

Around Christmas 1999 Central Europe was struck by two storms that caused severe damages. The two depressions of unprecedented intensity developed within 6 hours, starting with France bearing the brunt of the destructive winds. A major feature of these events was the failure of almost all the NWP models across Europe to provide adequate warning of the severe weather. However, the French global model Arpege succeeded to provide a reasonably good forecast, althought the size of systems was at the scales limit that can be resolved by this model. In our trial to find solutions to avoid such failures of the forecast models we investigate the lateral boundary formulations for one-way nested limited area models which seems to be one of the numerical problems in this case.

Limited area models (LAM) need information about the state of the atmosphere outside the integration area, so one of the inherent problems is the specification of the lateral boundary conditions which should serve a two-fold purposes. One is to be capable to smoothly transmit the large scale flow resolved by the boundary data into and out of the limited domain. The other is to represent accurately the outgoing waves and fine scale meteorological flow from the initial data and generated during the integration. Ill-posed lateral boundary conditions generate spurious gravity waves that propagate back to the domain. The most popular method to circumvent this in operational use is the so-called flow-relaxation scheme of Davies (1976 [1], 1983 [2]). The scheme consists of imposing the atmospheric large scale fields at the outer limit of the limited computational domain. A sponge zone is also defined just inside the limits of the domain in which large scale fields are gradually relaxed towards the nesting data. Damping is enhanced in the sponge zone.

The aim of this paper is to find out how much the forecast can be improved for the user who has data available only on a limited domain of a LAM. Our efforts have been concentrated on the study of the operational coupling scheme and later on the improving of it by the introduction of a spectral coupling method. At the beginning the weak points of the operational coupling scheme were studied in order to confirm that in some extreme situations the used coupling scheme is unefficient due to the use of a too long coupling interval.

2 SYNOPTIC SITUATION OF THE CHRISTMAS STORM

The first depression initially developed on the North American east coast. It was apparently restricted to the lower troposphere. It entered the exceptionally strong baroclinic zone that formed across North Atlantic where strong temperature gradients led to a strong polar jet with core speeds of more than 100 ms-1 at 300 mbar and temperatures and about 100km/h when it had reached the continent. This cyclone characterized by its small scale and its rapid development with high wind speeds was followed by another one at a very short time.

3 FIRST SET OF EXPERIMENTS. ALADIN/LACE OPERATIONAL TESTS

We concentrated on the features of ALADIN/LACE operational forecast for the Christmas storm case from 25 December 1999. ALADIN is a spectral limited area model with the lateral boundary conditions imposed by means of Davies relaxation scheme. The relaxation in ALADIN is done at the end of the time step, after gridpoint calculations, following the proposal of Radnoti (1995) [3]. The fields are provided in a compact spectral form at each coupling time. In operational applications the amount of available data is usually restricted for technical reasons. The model is coupled with lateral boundary data with a time resolution that is more an order of magnitude smaller than the time resolution of the coupling model, being determined by its model time step.

Many integrations of standard ALADIN/LACE model, using hourly Arpege global model forecasts as coupling files and applying them as lateral boundary conditions for the LACE domain, were done. The purpose was to study the impact of the coupling frequency by comparing the depth of the cyclone in the coupling and the coupled model near the entering time into the domain. Starting from the given data the model arrives to a surprising solution with 6 hours coupling frequency of updating the boundary files. In the MSLP field forecast valid for 06 UTC for 26.12.99 the cyclone is missing (Figure 1a), meanwhile using 3 hours coupling frequency the cyclone appears with the value for forecasted MSLP field of 976 hPa (see Figure 1b). As expected the cyclone is much better captured by 1h coupling frequency with a quite deep value 974 hPa in Figure 1c) the closest to the Arpege forecasted field (Figure 1d), the reasonably good for that day. The explanation of the missing cyclone in the forecast of the LAM is given by the fast

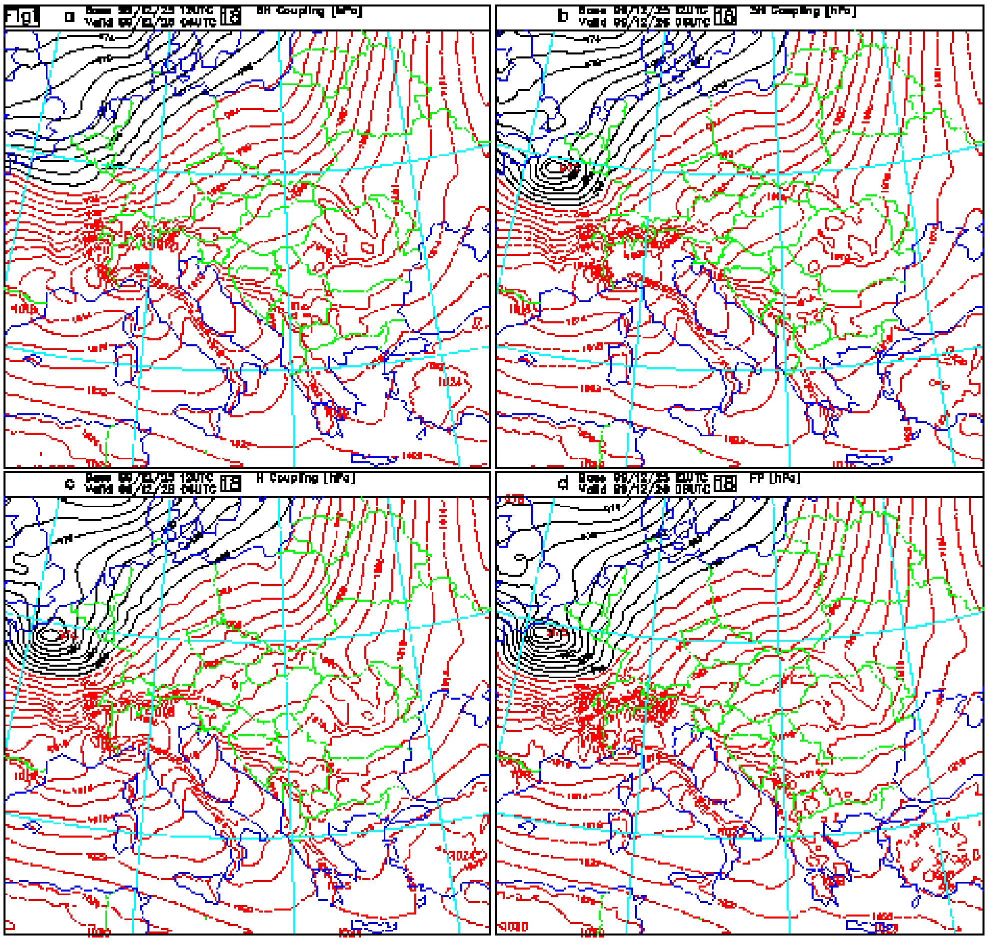

Figure 1: Impact of coupling frequency on MSLP field forecasted by ALADIN/LACE and ARPEGE valid for 26.12.99 06 UTC using Davies relaxation: (a) MSLP field of ALADIN using 6h coupling, (b) MSLP forecasted field of ALADIN using 3h coupling, (c) MSLP forecasted field of ALADIN using 1h coupling, (d) MSLP Arpege forecast.

speed of the propagating system which caused the absence in the coupling zone at the coupling times. If the system had no trace in the zone where the coupling is done at the first coupling time being outside the domain and at next coupling time fully inside the domain, it cannot be forecasted by the LAM in such cases with rapidly changing conditions. This could happen because the coupling model passes the information to the LAM only by its fields over the coupling zone at discrete times. The fields provided at a fixed coupling interval (in our case 6h) are linearly interpolated to obtain coupling fields at each model time step. The interpolation is mostly deficient here. At 00 UTC the storm was completely outside the domain and at 06 UTC completely inside. In this frame it is clear that the pressure low obtained by intepolating linearly the fields will never be as deep as in the zone where coupling is done. The passing cyclone was not picked up correctly. Unfortunately due to high computational costs the coupling fields cannot be available so often at such a short time interval as we would need (Figure 1c). Hence, we