Dynamics and coupling: themes for cooperation between ALADIN and HIRLAM

Introduction

Dynamical core in ALADIN is based on numerical choices which are intrinsically compatible. The back-bone is the spectral representation of model variables, which allows for a linear grid when using the semi-Lagrangian advection method. The semi-Lagrangian advection needs the semi-implicit filter to remain efficient. The combination of these four ingredients:

- spectral;
- semi-implicit;
- semi-Lagrangian;
- linear grid,

provides numerically a very efficient dynamical core, very suitable for NWP, completed by the terrain-following pressure-based vertical coordinate. Therefore, any new development should be designed and checked with respect to this core choice.

Once this is said we should mention that the coupling strategy has a bit special status, since there are even more constraints. Although the lateral coupling computation in ALADIN is a purely grid-point one, it is still strongly linked to the spectral technique. This link exists via the bi-periodic extension of the fields and also via the organization of the time-stepping algorithm. In addition, there are important practical aspects as far as the provision of the lateral boundary conditions from the master model to the coupled one is concerned. Therefore if we find a new promising coupling method, it is still half a victory before we are able to fit it in all the existing constraints. We may have easily the situation where we would loose a lot for gaining a little. But research will show; and maybe there will be a lucky idea as the one of Laprise discovering the natural way toward the Euler Equations.

The Laprise hydrostatic pressure vertical coordinate indeed opened the possibility to extend the efficient numerical methods from the HPE framework further to the fully compressible Euler Equations. In recent years it was possible to develop a robust and efficient solution using the class of iterated centered implicit schemes while keeping still a very simple semi-implicit solver of constant coefficients. We may say that it turned out to be very useful not to give up at the time of difficulties and not to drop out the above mentioned core stones of the efficient numerical approach. We believe that this spirit should be kept: the experience says that we usually find out a solution to the problems and that certainly it is worth trying before abandoning and changing everything (a radical change brings anyway more problems than solutions).

When developing the non-hydrostatic version of the dynamical core and knowing that it is going to be applied at the kilometric and hectometric horizontal scales, we took precautions and were testing its ingredients in academic and pseudo-academic conditions, including the so-called ALPIA test. Like that we could verify a few points regarding the efficiency of the semi-Lagrangian scheme in presence of sharp orography down to the hectometric scales, effect of the linear grid, orographic resonance and so on, in order to be on a safe side. The semi-Lagrangian scheme framework was used with advantage to develop the so-called SLHD (Semi-Lagrangian Horizontal Diffusion) scheme, offering an interesting solution for a scale-dependent horizontal diffusion.

Today we are at the point when the major part of the non-hydrostatic dynamical core is consolidated and when we may start an intensive experimentation on real cases. We still need to make a couple of cleanings in the code, to optimize it and possibly still improve the discretisation of some terms. Hence there is a bunch of small rather specific tasks, mostly already taken on in the ALADIN scientific plan for this year and they do not need to be developed here.

We rather believe that for the collaboration with HIRLAM we should list more strategic lines, around which other specific topics could develop. Work on these main issues can in principle start this year but it is sure that it will take longer, about two to three years. We believe as well from our own experience that around these main topics we may easier enlarge our “dynamical” team by the interested colleagues from HIRLAM than if the small side topics were proposed for the collaboration.

Main development lines are as follows:

1. Development of the TL/AD version of the ALADIN semi-Lagrangian scheme.

Status: In ALADIN, the TL and AD code exists for the Eulerian advection scheme. The semi-Lagrangian version exists in the global model ARPEGE and IFS.
Goal: To fill this gap and extend the TL and AD code from ARPEGE to the ALADIN geometry. The interest of this work is two-fold: it would enable to get a considerably more efficient AD/TL application for some later possible application of the 4DVAR algorithm in ALADIN; the interested person would get a useful knowledge and training on the semi-Lagrangian implementation as well as on the technique of the TL/AD coding. At first place the development shall be restricted to the HPE framework, Two-Time-Level Semi-Lagrangian scheme, generalized finite difference vertical discretization (encompassing the current ‘VFE’ scheme of ECMWF and/or any evolution of the latter that would make it compatible with the NH core constraints) and option NXLAG=3 (c.f. Tanguay et al., MWR, 1992, pp 113-123).

2. Improvement of the treatment of the map factor in the semi-implicit scheme of ALADIN.

Status: In the linear model used for the semi-implicit scheme formulation we use a constant value of the map factor, equal to the maximum value over the integration domain.
Goal: A recent linear stability analysis has shown that for larger domains than we typically use, it would be safer from the stability point of view to take into account for the variability of the map factor over the domain. This work should be seen as a continuation of the previous implementation of the rotated/tilted Mercator geometry, which was a nice compromise on how to enable the description of the existing HIRLAM geometry in the ALADIN system.

3. Investigation on a possible Vertical Finite Elements discretisation for the NH version of ALADIN.

Status: Current vertical discretisation in ALADIN NH is based on the Simmons-Burridge (1981) finite differences scheme.
Goal: To extend the ALADIN NH vertical discretisation scheme to the Vertical Finite Elements (VFE) approach (which is not a truly FE scheme but a finite difference one using all degrees of freedom of the vertical on the basis of weights computed like for a FE scheme). The motivation is that today IFS is using the 'VFE' scheme since it provides some advantages compared to the previous Simmons-Burridge finite differences scheme. It is believed to eliminate the potential existence of the spurious mode in Lorenz grid. More pragmatically it enhances the precision. Therefore by extending the NH configuration to 'VFE' we would be able not only to profit from the above mentioned improvements but also to harmonise the NH configuration with the IFS model. However this topic needs some theoretical work first due to presence of several numerical constraints applied in order to build the linear NH model used for the SI implementation. Some preliminary analysis was made by Pierre Benard but more theoretical investigation is needed before making any practical attempts.

4. "Well posed and transparent" boundary conditions coupling strategy for ALADIN

Status: Davies-Kallberg coupling/relaxation type of algorithm is used in ALADIN. It is advantageously combined with the so-called biperiodic extension of the model variables and semi-implicit scheme. It allows a cheap and efficient solution for a spectral LAM, not harming either the semi-Lagrangian or the semi-implicit methods implementation.
Goal: It is felt that for relatively small horizontal domains it would be more appropriate to use "well posed and transparent" lateral boundary conditions. Research on this topic has already started at HIRLAM (A. McDonald) and the issue is now investigated in ALADIN, too (F. Voitus), inspired by HIRLAM research results. The subject is however complicated; quite some theoretical and academic work is needed before thinking about any practical implementation. Among many important considerations it should be checked whether the new approach can be transposed to the ALADIN spectral formulation.

5. Investigation of the horizontal pressure gradient term in presence of sharp orographic slopes.

Status: The terrain-following hybride pressure type coordinate is used in ALADIN.
Goal: It is believed that at presence of very sharp slopes the current computation of the horizontal pressure gradient would be hampered by a non-negligible error. It would be therefore useful to investigate the practical NWP limits of the current scheme and possibly find such improvements which will not be in contradiction with the spectral-SISL method and will also respect the bottom boundary condition in the NH configuration.

6. SLHD: application at high resolution

Status: The first version of the SLHD algorithm is in operational use (still in combination with the HPE framework) at CHMI.
Goal: There are still a couple of issues to be investigated in parallel with the ongoing extension of SLHD to the NH model variables and to the pure grid-point advected variables (hydrometeors). For example the deformation diagnostics in the mountainous areas could be optimized with respect to the coordinate surfaces slopes. Further, we need to study whether

and how to couple SLHD with the 3D turbulence scheme. This work requires a lot of diagnostics and targeted experiments.