Current Status and Plans on ALADIN-NH Version

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I) INTRODUCTION

Similarly to previous years, a considerable activity has taken place in the domain of the NH version of ALADIN. There are basically two reasons for this : the horizontal resolutions used in operations in our countries for LAM applications are now approaching the limit for which the hydrostatic hypothesis is no longer valid; and more specifically for Météo-France, the AROME project needs in 2003 a reasonable basis of evaluation for choosing between two dynamical cores to be considered for the future mesoscale NH operational application planned in 2008 (Meso-NH or ALADIN-NH).

The activity has been mainly devoted to demonstrating the possibility of a NH version robust enough to allow a significant benefit from using semi-Lagrangian (SL) schemes and their long time-steps. We can say that this goal has been reached, and that we have now a good hope that future mesoscale applications of ALADIN-NH will be at the cutting edge in terms of robustness and cost-effectiveness compared to other more advanced applications in the world.

Some other activities have taken place and will be reported as well here.

Concerning the cooperation and human point of view, the work of the small "ALADIN NH community" have been very enjoyable and fruitful. It is worth noting that the capabilities of the CHMI-SHMU group (J. Vivoda, J. Masek, P. Smolikova) in the area are rapidly reaching a top level, and there is no doubt that this small (promising) Eastern nucleus will overrun its French (declining ?) counterpart (P. Bénard, J.F. Geleyn) in future years.

II) WORK DONE FOR STABILIZING THE ALADIN-NH VERSION

1) Implementation of ICI scheme

The program initiated few years ago for implementing an Iterative Centred-Implicit (ICI) scheme, and performed in the framework of the PhD work of J.Vivoda, has received a considerable progress. This scheme, which is more robust and sophisticated than the old Semi-Implicit (SI) scheme, has been widely validated and implemented in the official code library of ALADIN since CY25T1. Although in this first implementation the totality of the desirable options are not coded (e.g. only 2TL versions are coded, not Leap-Frog ones), this allows a wide community to use and test this new scheme extensively.

It is to be noted that the implementation of the ICI scheme has been accompanied by a deep rationalization of the gridpoint part of the adiabatic computations, which makes the new code more readable than the old one in spite of its more sophisticated character.

In parallel, an action for harmonizing the ALADIN and IFS codes of ICI schemes has been initiated in order not to result in a too much complicated code. However, ECMWF decided recently to abandon their version of the ICI scheme, hence this action becomes obsolete and will be re-oriented simply in the cleaning of this option from the ARPEGE/IFS code.

2) Implementation of new prognostic variable (*d4*)

After the demonstration of a benefit in terms of robustness when using the prognostic variable "*d3*", another step was done by introducing a new prognostic variable "*d4*" (see P. Smolikova's paper in the same volume for details). The code for this new variable has also been introduced in the official code library of ALADIN from CY25T2 in order to allow extensive testing.

It is to be noted that the code for this new variable is a little bit more complicated and heavy than for older prognostic variables up to *d3*. As a consequence, a significant benefit will be required for this variable to be kept in the code. This question is the one to be answered to after more testing.

3) Implementation of a w prognostic variable

In order to try to remove a distortion of the response of ALADIN-NH in SL mode, compared to the correct Eulerian response, a prognostic *w* variable has been introduced in ALADIN during the visit of Christopher Smith. This code has also been implemented in the official ALADIN library from CY25T2. However, there are currently two flaws with this code : first it has a lack of scientific justification, and second it is not fully debugged and does not work properly. The status of this piece of code needs to be discussed and examined scientifically more in detail, since it will not be kept in the code if the SL distortion response can be removed in a more simple way.

III) WORK DONE FOR TESTING THE ALADIN-NH VERSION

Implementation of the two previous key ingredients (ICI and *d4*) in the official ALADIN code library has led to a wide spontaneous stream of testing in all directions. This is a good point since the corresponding changes are quite deep and must be extensively tested before acceptance by the community. For the use of ICI scheme, it can be observed that there is an emerging consensus in a significant part of the fine-scale NH modelling community in the world to say that the SI scheme may not be sufficient to insure an acceptable robustness (as was claimed by Tanguay et al., *MWR* 1990), and that more sophisticated schemes such as ICI schemes are required. The position of ALADIN on time-schemes is thus not a position of "isolationism".

Testing has been done in the following adiabatic frameworks :

- Classical academic set of 2D bed-tests of the NH group (flows over orography)
- Specific severe 2D tests for the AROME project
- Quasi-academic 3D tests for the AROME project
- 3D PYREX case
- 3D ALADIN-France (summer) case

A general conclusion is that for ICI schemes, a single iteration (on top of the normal SI-like iteration) should normally be enough for insuring the desired robustness. In this case, the scheme is sometimes called "Predictor/Corrector" or "PC" scheme, since the first SI-like iteration is a predictor iteration, and the additional one is a corrector iteration. Contrary to the UKMO approach, both predictor and additional iterations are based on the solution of an implicit equation : this is thought from our side to result in a better robustness.

A significant increase of robustness has generally been observed in the tests performed so far compared to older existing versions of ALADIN-NH, and even we have been able to give some "scoops" (e.g. first successful nonlinear NH integrations with 2-TL schemes, due to the use of the ICI scheme). However, the choice of the optimal combination of all the new functionalities is not easy because it seems to depend on the practical configuration examined. In case of difficulty in this area, the criterion would of course be the optimization of the robustness in the projected operational-like context.

However, after this phase of "enthusiastic testing", a phase of synthesis will be necessary to localize the areas of weakness, and to conclude more firmly, in order to possibly remove useless options.

IV) SHORT-TERM PLANS

1) Accuracy problems in SL

Since we are now almost convinced that a satisfactory final choice of the time-scheme and prognostic variable is available in the ALADIN code (hence potentially solving the robustness problems), the next priority is to study the problem of accuracy : in effect, as said above, a distortion of the response of ALADIN-NH appears when a SL scheme is used, compared to the correct Eulerian response. There is indication that this problem may be correlated to the discretisation of some nonlinear terms or to the formulation of the Bottom Boundary Condition (BBC). A significant part of the working force (including the possible help of some newcomers) will be progressively oriented towards this topics from the beginning of this year, since this appears to actually be the next burning subject.

2) Choosing and pruning obsolete options

After more extensive testing will have been performed, a necessary step will be to remove the less interesting options of the ICI and *d0-d4* code. These provisional options had been coded originally because there was no obvious way to decide what were the best scientific choices, and practical testing often allowed to answer these questions. One of the most important pieces of code concerned here is the "LPC_NOTR" option of the ICI scheme, in which the trajectories are not iterated. This allows to gain a small amount of computation at the possible expend of a potentially slight and acceptable decrease in quality. This option could have been interesting for operational use, but it appears that the potential benefit is small compared to the disadvantage of a very heavy and inelegant code. Various sub-options of the *d4* variable will have to be removed as well. Removal of *d0-d2* and $\mathcal{P}1$ prognostic variables will also have to be considered.

3) New Linear operator

There is an indication that a slight change in the linear operator could contribute to a further increase of robustness especially for the 2TL schemes (see P. Bénard's paper in the same volume). This small topic will be explored in more details in Toulouse.

V) LONGER TERM PLANS

1) Inclusion of the physics

So far, few attention has been paid to the robustness of ALADIN-NH when the physical package is turned on. For instance, some 3D experiments exhibit strange behaviours when the physical package is abruptly turned on. There is hence a potential danger of bad surprises in this domain although the possible associated problems should not become insurmountable hopefully. Anyway, this problem will be partly tackled by the AROME team, and the initial work in this area should be done in Toulouse.

2) Deep atmosphere for NH

Recent examination of the extension of Euler Equations to the Deep Atmosphere (i.e. removing the Shallow Atmosphere approximation) shows that this can be done very naturally if the hydrostatic pressure-based coordinate is generalized to a mass-based coordinate (see forthcoming paper by Wood and Staniforth, *QJRMS* 2003, WS03 hereafter). The amount of changes in the model should be much less than the one needed for implementing the older White and Broomley (1995, WB95 hereafter) approach. The advantage of this new WS03 approach is hence twofold : the extension is absolutely exact (the WB95 approach contained an ad-hoc approximation), and it is much simpler. The generalization of the coordinate from an hydrostatic pressure to a mass coordinate is purely conceptual and has very few code consequences in itself (similarly to the extension from pressure to hydrostatic pressure when going from hydrostatic to NH equations).

This work has of course a lower priority, but could be initiated in future years, once "immediate pressure" for other topics will decrease. It is to be noted that the extension to the deep atmosphere (altogether with the release of some similar approximations) is sometimes claimed to become important for the small-scale modelling with typically 2 km horizontal mesh.

VI) COMMUNICATION

The ALADIN-NH community has worked so hard these two past years that the aspects of communication have been somehow pushed into the background. In 2002, one oral communication has been performed:

"Alternative time-discretizations for mesoscale applications: some results". P. Bénard, J. Vivoda, P. Smolikova, J. Masek. SRNWP-NT mini-workshop, Toulouse, 12-13 December 2002.

Additionally, one publication has been submitted:

"Stability of Semi-Implicit and Iterative Centred-Implicit Time Discretisations for Various Equations Systemes Used in NWP", P. Bénard, Submitted to *Monthly Weather Review*.

It should be noted that this latter paper sets the theoretical and methodological framework for a series of planned subsequent papers on connected aspects, to be written during next months. A significant effort will also be devoted in next months to the rewriting of the ALADIN-NH documentation.