# Report of fifth SRNWP-NT mini-workshop

**5-6 December 2006**

**Zagreb - Croatia**

P. Bénard *(Coordinator for SRNWP-NT)* 20 march 2007

## Introduction

Thanks to the very kind invitation of the Croatian Meteorological and Hydrological Service, the fifth SRNWP-NT mini-workshop was held in Zagreb on 5-6 December 2006. This two-days mini-workshop consisted in 9 presentations, each one followed by informal discussions on the topic. For most of presentations, the length of discussions was significantly longer than the presentation itself, which indicates that the format and the informal fashion of the workshop are fruitful. Beside these presentations, specific discussions were held at the end of each sessions, and a general discussion took place in the afternoon of the second day. The electronic version of presentations has been made available at:

`http://radar.dhz.hr/~ivateks/SRNWP_NT_WS/`

Representatives of EUMETNET, ALADIN, ECMWF, HIRLAM, INM/RAS and UKMO groups were present.

The topics of presentations were quite various, and involved pure physical aspects (Wood), Physic/Dynamics coupling (Termonia), SL formulations (Zerroukat), LBCs (Voitus), time-stepping (Diamantakis), spatial discretization (Vivoda), as well as implementation aspects (Tolstykh, Wedi, and Bénard).

## Presentations

A comprehensive formulation of a new implicit off-centred time-discretization for vertical diffusion schemes was presented by N. Wood (this is valid for any scheme formulated with exchange coefficients, hence including so-called TKE schemes). This numerical formulation of the off-centring parameter is mainly based on numerical/physical requirements (accuracy, monotonicity, stability, etc.) rather than on phenomenological requirements as it was for the type of time-discretizations used in Kalnay, Girard, or ARPEGE/IFS formulations. Here, the non-linear dependance of the local exchange coefficient is not considered in itself, but represented by a constant exponent. From a practical point of view, this approach however needs to reintroduce some phenomenology to cope with the large differences between stable and unstable layers. The implementation needs two passes in the implicit tridiagonal solver for each column (instead of only one for current schemes), but seems quite efficient for economically curing the oscillation problem which often constrains the length of the time-step in our models.

Concerning Physics/dynamics coupling, an overview of the work done in Aladin project for improving the guidance of new developments was presented by P. Termonia. The goal is to develop a framework allowing more flexibility for the inclusion of the physics in the model time-step, and namely, the possibility to incorporate the so-called "SLAVEPP" IFS stepping, while trying to eliminate inconsistent formulations.

The different approaches for physics inclusion are:
- at time $t$ or $t + \Delta t$
- at departure or arrival point of SL trajectory
- parallel or sequential physical processes
- parallel or sequential coupling to dynamics.
The analysis for guidance is based on an extended framework of Staniforth et al. (2002) analyses. Although a fully conclusive guidance is not easy to achieve within this framework, results are encouraging and confirm that the two opposite ways chosen for the AAA (ARPEGE/ALADIN/AROME) and SLAVEPP approacheshave their own consistency.

An overview of the progresses made at ECMWF in using the NH dynamical core of ARPEGE/IFS were presented by N. Wedi:
- the noise occuring in previous run was found to be due to an inconsistency in Horizontal Diffusion of horizontal and vertical velocities, which was removed afterward.
- the temperature problems previously observed when using physics can also be removed by setting proper value for the model parameters.
- in adiabatic mode, the forecasts appear to be almost identical to HPE ones (everything else being identical).
- several choices can be tested regarding to the inclusion of physical tendencies insides the iterative time-stepping.
Globally, the results are encouraging, although the model still needs improvement to compete with the operational one. The possibility to include the IFS Vertical Finite-Elements (VFE) discretization in the NH kernel will be the key issue for the next months.

M. Zerroukat presented the 3D version of the UM semi-Lagrangian conservative SL scheme (SLICE) with some validation experiments. This scheme, in opposition to 3D remapping volume approaches, uses only 1D remapping computations, not only along straight lines, but also along distorted "Lagrangian" lines. This makes the schemes much more simple and efficient. The results presented with the monotonic version on idealized global simulations showed an improved conservation compared to the traditional SL approach of the UM.

The formulation and some preliminary results from the variable resolution of the Russian Met Service, were presented by M. Tolstykh. The formulation with vorticity-divergence and the semi-implicit scheme use a mixed solver with a direct Fourier solver in the longitudinal direction and a compact grid-point solver in the latitudinal one. The variable resolution is achieved through a discrete transformation along latitude directions, with the future possibility of a rotated pole. The model successfully passed standard test cases, and preliminary results on quasi-operational mode were presented.

The work done by F. Voitus in Aladin for trying to improve the coupling scheme at the lateral boundaries of the domain was reported. Two main strategies were explored: transparent, well-posed LBCs inspired from the works of McDonald, and new absorbing layers based on better mathematical sounds, as Perfectly Matched Layers. Although spectral models do not lend themselves easily to a transposition

of McDonald method (designed for finite-difference models), it seems possible to achive comparable results by making the computation of implicit coupling independant of the dynamics, but this reveals rather expensive. On the other hand, for strategies using absorbing layers, the new formulations recently proposed seem to offer encouraging perspectives, though their applicability to the problem of NWP is not yet completely clear.

The implementation of an iterative semi-implicit scheme in the UM was described by M. Diamantakis. The approach is similar to what is already done in other models, except that inside each iteration, the UM predictor/corrector scheme is conserved for reducing the magnitude of the explicitly-treated non-linear residuals. As a result the model has two nested levels of iterations for the time-stepping itself (the innermost iteration being the predictor/corrector scheme). The results with this new time-scheme showed an improved stability and accuracy, as experienced in other services especially for NH applications. For the UM, this iterative scheme seems to outperform the normal scheme since, although 60% more expensive, it often makes possible a doubling of the time-step length.

The status of research NH applications at Meteo-France (AROME, ARPEGE/Aladin) and the current works for implementing more general linear solvers in the dynamical kernel were presented by P. Bénard. These more general solvers might be needed in view of large LAM domains (with large map-factor variations), non-isothermal SI reference states, and/or VFE-NH discretizations. In this case, the algebraic elimination would not be pursued until elimination of all but one variables, and the solution of the linear implicit system would require an iterative process.

The works about VFE discretizations of the Aladin NH kernel were presented by J. Vivoda. In addition to vertical integral operators, the NH model needs a VFE-based definition of vertical derivative operators, which must satisfy a number of constraints in order to insure a stable scheme. Finding a solution which fully satisfies these constraints is not yet achieved, but some formulations seem to be viable, at least as far as the linear terms are concerned. Results of academic cases were shown with this VFE scheme.

## Discussions

The main questions about the new Vergical Diffusion time-stepping presented by N. Wood were: (i) the compared cost with predictor/corrector approaches, in the case of a model which is itself based on an iterative implicit scheme for the main dynamical part as presented e.g. by M. Diamantakis: in this case the approach presented by N. Wood seems to loose a great part of its attractiveness. (ii) the space and time variations of the resulting off-centring factor, since chaotic variations may be the indication of a pathological behavior of the formulation, leading to possible instabilities. Diagnosis on this point would be valuable.
Concerning the works on the NH version of IFS/ARPEGE, even if noticeable progresses have been done, and the model can be run stably with "hydrostatic" time-steps, it is recognized that more work is needed: the reason why the horizontal diffusion must have the same strength on horizontal and verical motions must be investigated, and the adverse effect of IFS phys/dyn interface must also be better understood, before the kernel can be judged as potentially viable. Then, the more vast problem of introducing VFEs

in the NH kernel will be the priority: many approaches are possible and remain under investigation so far.

The discussions about LBCs in LAMs showed that the problem is quite a serious one, and it seems that no immediate solution is in view at short term. As a result, Davies relaxation is still used in every Services. Noticeable is the quite untypical position of UKMO among European Services, since for getting rid of LAM LBC problems, they might preferably consider the possibility of discrete highly stretched approaches as e.g. the one used in GEM model. This raise the question of highly stretched geometries (in forecast and assimilation modes) which has not been revisited since long time.

The results presented by M. Diamantakis were extensively commented. It was agreed that they reflect the general feeling with respect to these iterative schemes, allowing a more implicit treatment of (non-linear) source terms. One of the main issue however, is the convergence of the iterative algorithm. It should be interesting to evaluate after how many iterations the algorithm typically converges and what is the limiting time-step which insures convergence. Also, apparently, the presented scheme did not allow to completely remove the various off-centring parameters, which may be viewed as an intriguing result worth to be studied. Finally, the respective impact of iterating trajectories and non-linear sources would be interesting, especially in view of evaluatiing the relative impact of implicitly recomputed trajectories, as discussed in the recent paper by Cordero et al. (Q. J. R. Meteorol. Soc.).

The discussions about VFE discretization for the NH kernel of IFS/ARPEGE/ALADIN mostly involved three points: (i) at the level of continuous equations, what are the sets of prognostic variables which make non-linear thermal residuals vanishing in the so-called elastic term $D_3$? The current set ($d_4$, $\widehat{q}$) is one of those, but maybe not the only one. It might be advantageous to find such a set which would also have the property not to contain divergence-based vertical momentum variable; (ii)with such sets of prognostic variables, is it possible to derive the linear stucture equation by making use of less constraints than currently ? The current constraints (C1) and (C2) are a serious obstacle for designing a VFE scheme in the NH kernel; (iii) Although a shift to more complex implicit solvers may be a viable solution for solving the problems posed by VFE discretization, the research of VFE vertical operators leading to a complete algebraic linear elimination (and thus to the inversion of a simple so-called "$L*L$" implicit system) should not be abandoned since they would provide a much simpler solution.

## Final discussion

The very end of the workshop was devoted to the new functionning of the SRNWP-NT network, according to Eumetnet plans. After discussions, it was decided to keep the same name and same areas of interest for the SRNWP-NT network, and also the same dimensionning for the meetings (i.e. rather informal meetings with few participants, and with a large part dedicated to free discussions beside presentations). According to Eumetnet rules, the "Leading Centres" will be replaced by "Working Groups" (WG), who will take in charge collectively the animation of the networks. A first draft of the content of the WG (with one person from ALADIN, COSMO, ECMWF, HIRLAM and UKMO) for SRNWP-NT was proposed. From the side of the COSMO consortium, Michael Baldauf should be asked for becoming the new representative in replacement of Jürgen Steppeler, soon retiring.