SRNWP Mini-Workshop on Numerical Techniques

Meteo-France, Toulouse, 12-13 December 2002

I) OVERVIEW

The areas of interest for the Working Group have been divided into five topics, on which active research is being done

1) Semi-Lagrangian
2) Time and Space Numerical Schemes
3) Numerics of Physics-Dynamics Interface Schemes
4) Orography
5) Shared academics experiments

II) REPORT OF TALKS

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1) Semi-Lagrangian

Despite the renaming of the working group (from "Semi-Lagrangian" to "Numerical Techniques"), a significant level of activity is still taking place in the Semi-Lagrangian. However, most of the basic numerical problems linked to the operational use of SL schemes for NWP seem to be solved, and the main focus is now set on refinements of the properties of the scheme, as e.g. conservation, definite positiveness, monotonicity, etc.

Among the Groups participating to the SRNWP Network, UKMO and HIRLAM Groups have an active position for these topics, since they examined formulations trying to achieve the above desirable properties.

While HIRLAM CISL (Cell-Integrated Semi-Lagrangian) scheme is monotonous, mass-conserving, definite positive, and is implemented successfully in a shallow-water model with semi-implicit treatment of the inertia-gravity waves, it results in a significant increase of computation and storage, and the required spatial truncation could result in exaggerated diffusive properties. A strategy for the 3D formulation has already been defined.

The SLICE (Semi-Lagrangian Inherently Conserving and Efficient) scheme of UKMO, based on a cascade interpolation is conservative (but not monotonous) and is implemented in 2D. However it

seems to be cost-effective and could possibly be extended to 3D with no major difficulty, leading to a possible application for NWP in short terms, a perspective which will be followed with interest by the other partners of the Network. The authors also claim that their scheme achieves competitive or better accuracy than that of standard non-conservative interpolating semi-Lagrangian schemes.

ECMWF expressed their current interest in also studying the possibility of using more conservative schemes (possibly based on cascade interpolations).

The Institute of Numerical Mathematics of the Russian Academy of Sciences is implementing a finite-difference 2D SL model with a variable resolution unstaggered grid, which requires choosing the vorticity and divergence as prognostic variables. This minimises the number of trajectories and interpolations and results in a cost-effective model. The extension to 3D is straightforward.

ECMWF reported a case for which the so-called SETTLS (Stable Extrapolation Two-Time-Level Scheme) used for the 2-Time-Level SL was not enough to prevent the growth of an instability over Antarctica. In the absence of a better proposal so far, the problem, identified in the vertical part of the trajectory computations, was solved by using selectively a first-order vertical trajectory scheme instead of the usual second-order scheme at places and time where the instability is suspected to occur.

2) Time and Space Numerical Schemes

A significant level of activity is arising in this field, especially in application to nonhydrostatic systems. RPN de Dorval (Canada), although not present at the workshop, is also participating to developing this area of interest.

UKMO Group analysed the numerical stability and accuracy of the 1D and 2D versions of the New Dynamics (ND), in particular top and bottom boundary conditions of potential temperature (ND uses the Charney-Phillips staggering in the vertical) for isentropic and isothermal basic state. They identified pathological combinations of the BC, which were subsequently removed from the operational use.

ALADIN Group used a very similar approach to show the beneficial impact that can be expected from using an Iterative Centred Implicit scheme to solve their Euler Equations system with an enhanced robustness. Using this scheme, Aladin-NH was shown to be able to perform stable integrations of a real case at mesoscale resolution with a 2-TL scheme free of any artificial stabilising feature as decentring or others.

3) Numerics of Physico-Dynamical Interface Schemes

HIRLAM Group is still continuing investigations on the best way to include physical tendencies in the time-loop of their dynamical model-core (2TLSLSI). They found better results and a significant decrease in the sensitivity to the time-step length when using tendencies averaged along the SL

trajectories, as done at ECMWF. Some tendencies can also be optionally averaged in time.

UKMO Group is building an analytical framework to study this issue from the theoretical point of view. Their aim is to compare the various possible physico-dynamical interfaces in terms of stability, accuracy, steady-state response of the forced solution and resonant response. The approach takes into account various formulations of the time-discretisation of dynamical or physical forcings, but ignores the details linked to the different individual physical parameterizations.

4) Orography

COSMO Group is still studying alternative solutions to terrain-following vertical coordinates which, they claim, could become problematic with very steep orography. The main problems are

- the generation of spurious local circulations over very steep slopes (probably due, at least partially, to the inaccuracy in the horizontal pressure double term)

- the exaggerated intensities of the precipitations, very probably due to too strong a vertical component of the wind.

In their shaved-element method, a merge of adjacent elements is used to avoid over-restrictive CFL stability conditions. The method is shown to be effective, and leads to reasonable results.

However the other SRNWP Groups do not seem to face severe problems with the use of terrain-following coordinates so-far. It must be nevertheless said that they avoid the problem by smoothing the orography.

From the physical point of view, the COSMO Group also stressed that more attention should be paid to the definition of the orography and its links with the precipitations. They are now testing a precipitation scheme with explicit horizontal advection of the precipitation. This scheme should transport precipitation to the lee side of the Alps where a systematically deficit occurs. The COSMO Group has still no solution for the "roughness length dilemma" over mountains. The problem is that the large roughness lengths requested in order to have correct momentum fluxes and momentum budgets reduce far too strongly the surface winds when compared with observations. This problem has also been recognised and studied by the UKMO Group which also has no "universal" solution (i.e. a parameterization satisfying both aspects).

5) Shared academics experiments

The usefulness of this field of activity is usually strongly advocated by UKMO group. This year, a "demanding" academic experiment has been submitted to 4 groups (HIRLAM, UKMO, ALADIN, and the French Meso-NH which was at the origin of this test). The settings and the results have been presented by the ALADIN group. The case is demanding since it involves a non-stationary non-linear trapped lee-wave which needs a good numerical scheme in order to be simulated satisfactorily. The French groups ALADIN-NH and Meso-NH did extensive experiments in order to get a good knowledge of the behaviour of the system, and obtained quite similar results. UKMO performed a preliminary experiment which exhibited some slight differences, which should be explained by some further experiments. The HIRLAM NH model gave significantly different results.

II) COMMENTS

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1) Semi-Lagrangian

The problems of conservation, monotonicity and definite-positiveness are still of actuality, but only if they can be solved with computationally efficient schemes. Simple "corrective" schemes as the quasi-monotonous option in the ARPEGE/IFS model are not necessarily the best solution (this option is abandoned for the vertical part of the moisture transport in IFS). However, simple algorithm such as cascade interpolations will be considered with interest for NWP if they are confirmed to provide a good solution at a reasonable cost.

The 2-time-level SLSI (Semi-Lagrangian with Semi-Implicit) scheme is still at the limit of stability when large time-steps are used. Despite the SETTLS extrapolation, the SLSI scheme seems to exhibit unstable behaviours under certain conditions in the IFS.

It must be noticed that the interest for local mass conservative advection schemes does not come from the short-range NWP community, but primarily from the climate simulation scientists. For their GCM, they need mass conservation, particularly conservation of the water vapour.

There is definitely a revival of the cascade interpolation. But it must not be forgotten that this technique cannot be applied with a reduced grid.

2) Time and Space Numerical Schemes

The need of a deeper understanding of the behaviour of efficient numerical schemes especially in emerging NH models is a clear tendency. UKMO and Aladin-NH Groups achieved in some sense a remarkable convergence on this issue. To be well accepted, numerical schemes should ideally prove their suitability with theoretical arguments. Analytical studies often lead also to a greater potential for innovative ideas. UKMO and Aladin-NH Groups agreed to share more activity in this field in the next future.

3) Numerics of Physics-Dynamics Interface Schemes

The coupling of the physics to the dynamics seems to be still a burning question in spite of the small number of talks on the subject. Each Group is more or less working on the subject even if it is not the main activity pushed in the flood-light. The question of the detrimental effect of only first-order accuracy in time for the inclusion of physical parameterizations is apparently concerning more than

one Group.

4) Orography

The COSMO Group still seems isolated inside the Network, when pointing to the unsuitability of terrain-following vertical coordinates for horizontal resolutions of a few km over the Alps. A possible explanation is that even if the problem actually exists, current NWP applications are maybe not approaching the dangerous steepness. It would be interesting to better quantify when terrain-following coordinates will be so bad that they must be abandoned. This makes this topic a perfect candidate for the proposal developed in item (5) below.

5) Shared academics experiments

Shared experiments can be viewed from two points of view:

- (i) Comparison of results (and models) on a given fixed experiment
- (ii) Tool for trying to compare options which are not under switch for any available model.

The first approach has been used for the experiments described above for the non-linear non-stationary trapped lee-wave experiment. However, this exercise has its own limits which are easily reached. We claim that the second approach could be more fructuous, and we propose to promote it in the future instead of the first one. A formal proposal in this way will be sent to all SRNWP-NT participants, with more details on the motivations.

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