LACE Working Group for Dynamics & Coupling:

Research plan for the year 2006

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Introduction

This paper aims to give impression about the areas of research on the fields of dynamics and coupling which seems to be of the RC LACE interest. Aiming the given amount of resources (available researchers and the LACE research funds) not all topics are feasible to be studied during the year 2006. They are however listed here for a case some new impulse would appear later (an extension of existing research, unexpected revision of priorities as a consequence to other research conclusion or problems discovered during an operational experience). Such topics may also possibly attract new people interested about research in dynamics and coupling.

Traditionally the proposed plan is structured into three following sections:

- I. Non-hydrostatic dynamics
- II. Dynamics - more general topics
- III. Coupling

Each subject is labeled by the priority estimation with following meaning:

1 The subject has the highest priority. It is desirable to finish most of the work during a given year leaving no (fundamental) uncertainties for the future.

2 The subject has either some potential to directly improve the operational model performance or it is very close to be finished. For the long term research it represents subject which should be sooner or later done in any way.

3 The subject is currently relying to another related research. In this category are also subjects for which it is not clear whether their implementation would bring direct improvement of the model performance (at least when considering also the requested code implications and CPU cost).

Note that the priority number for a given topic is subject of the temporal model know-how. It can be easily modified once new circumstances would imply it.

1 Non-hydrostatic dynamics

- **Iterative schemes**

  Description and objectives: The stable iterative scheme (ICI scheme) is available in the model for the 2TL SL time-stepping and Eulerian advection. There are several possibilities to further generalize the existing code (like extension to the 3TL SL advection) but none of them is currently of really high priority. More useful would be to verify ICI performance for specific cases or with rarely used or new model options. Finally there are variety of options for the physic/dynamic interface offered by existence of the iterations during one time-step evaluation. As it is known this point should be studied with respect to a specific physical package. This means that such study should not be performed independently to the work defining the the physical package for the operational model.

  Priority: 2-3

  Possible contributors: JV, MT, ...

  Means: No action planned for 2006

- **Further improvement of the NH dynamics**

  Description and objectives: As it has been shown the convective bubble test indicates some deterioration of the d prognostic variables performance with respect to the hybrid w one. This result from a very sensitive academic test has probably just small impact for the real atmospheric model simulation. It however indicates that there is still a space to further improve the NH core.

  One of the suspicious places of the NH dynamics is the discretization of the so called Z-term. A specific study diagnosing some other approaches for this term can give clear answer to the source of the limited model performance.

  Another known place to further improve NH performance is the BBC treatment. The problem has been nicely withdrawn by usage of the grid-point horizontal diffusion (SLHD) instead of the spectral one. However there is still a theoretical chance to make this way even more consistent with the BBC. Before distinctive end of the chimney story it would be nice to check whether this possible option has really the potential to improve the existing BBC computation.

  Finally when the results from the real cases of the non isothermal SI background option confirms expected increase of model stability, the propagation of this currently isolated research into the common source code would become a necessity.

  Priority: 2

  Contributors: RB, MV, JV

  Means: 1.5 month

- **Diabatic forcing in fully compressible model**

  Description and objectives: Diabatic terms in the model are currently modified in order to fulfil the so called hydrostatic adjustment parameterization. The idea behind is to avoid direct generation of the acoustic waves. This arrangement creates some inconsistency in the model equation. Thus it can be a source of the potential problems. Logically more consistent would be to implement the diabatic terms in agreement with the theory. In the framework of the 2D academic and 3D real case experiments the exact implementation was studied. The results were quite promising but no real profit from exact solution implementation was detected (despite the fact, that diabatic term can be implemented without any simplifying assumptions). More various tests has to be performed in order to give clean material for the final decision. Knowing also that the final solution rely on the clear phys/dyn interface, it is entirely linked to the progress reached on the area of phys/dyn interface (equation part).

  Priority: 3

  Contributors: AT

  Means: No action planned for 2006

- **Vertical finite elements discretization of NH scheme**

  Description and objectives: To obtain higher accuracy and get rid of the unstable nodes the vertical discretization of the NH dynamics can be further improved by the vertical finite elements scheme. There is also a strategic issue: The ECMWF is currently looking for a NH core for the IFS model. Logically it is also of our interest that it should be based on the same assumptions as the current ALADIN/ARPEGE NH dynamics. Otherwise we would face the schism of having two independent NH dynamics in one code. Since IFS is using the vertical finite elements scheme for their discretization it is desirable to implement this scheme as well to the NH dynamics. Recently two people from HIRLAM (Karina Lindberg and Bjarne Andersen) accepted to work with Pierre Bénard on this topic. LACE however with their strong NH team feels some responsibility for the development and maintenance of the ALADIN-NH dynamics. Consequently as agreed LACE should not completely ignore this important subject. Especially when the HIRLAM scientists are quite new in the ALADIN NH dynamics. Hence LACE is devoting JV to work jointly with the HIRLAM team introducing them to the NH code and providing them to the necessary expertise.

  Priority: 1

  Contributors (LACE): JV

  Means: 3 months (1 by LACE support)

2 Dynamics - other topics

- **Theoretical studies linked to the vertical discretization in high resolution**

  Description and objectives: With the intention to run operational model on kilometric horizontal mesh, the model considerations should be carefully revisited. Within many of them the vertical discretization (possible usage of more precise approximation, study of problems caused by terrain following coordinate above steep orographic features,....) should be verified for such scales.

  There are variety of new ideas and proposal in this area. However each serious work should start by the analyze of the existing problems in our model. Once it is clear there is something causing potential danger to the model predictability, the next step would be to propose (or to use something already proposed) and implement safer and more reliable scheme.

  This subject is not the urgent one. However it has to be once done especially when the continuous trend of the operative application to increase their resolution. As soon the revision starts, the research will be safer in the future.

  Priority: 2

  Contributors:

  Means: No action planned for 2006

- **Improvement of the approximation of the horizontal pressure gradient term**

  Description and objectives: Other research topic linked to the increasing resolution of our models is the way how the horizontal pressure gradient term is approximated. It is known that especially in presence of sharp orographic slopes the current treatment of this term has some limits. The topic has been already accepted by the HIRLAM scientist (Ulf Andrae) who will work with help of RB.

  Priority: 2

  Contributors: RB with others

  Means: 1-2 weeks for supervision

- **Horizontal diffusion schemes for the regions with orographic features**

  Description and objectives: There are currently two horizontal diffusion schemes available in the model. Both of them tends to have some problems close to the orographic features.

  The spectral diffusion acting along the sloped model levels is known for its potential to destroy valley inversions or to create false advection from air mass being above other air mass with different characteristics. This known weakness is reduced in case of temperature field by diffusing just the temperature difference from the standard atmosphere. This solution is anyway not always sufficient. The other fields are not vertically corrected at all. A targeted study can diagnose the impact of spectral diffusion, eventually to propose some solution for the diffused amount.

  SLHD acting more locally within one 3D stencil of the semi-Lagrangian interpolation seems to have less problems with the false advection around sloped terrain. Its triggering function - the horizontal deformation function is however computed along model layers. It is evident that in mountain areas such function is consequently enhanced by the impact of the sloping surfaces. The diffusion performed by the SLHD is then randomly stronger for such areas. Again this effect should be studied more in detail. If serious problems for the scheme performance is detected a solution to solve it should be proposed during this study.

  The work should be based on idealized tool (2D or 3D) with horizontally homogeneous stratification. The impact of "horizontal" diffusion scheme in the presence of a orographic feature then would be studied under this clean test-bed.

  Priority: 3

  Contributors:

  Means: No action planned for 2006

- **Radiative upper boundary condition**

  Description and objectives: An analysis of the recursive filter based on the non-reflecting upper boundary condition (RUBC) for gravity and acoustic waves interaction with the semi-implicit temporal scheme was carried on. The main concern was to influence the phase speed of the waves caused by a SI scheme on the radiative performance of RUBC. It was suggested that RUBC should be kept in an explicit form in order to properly handle wave radiation. The scheme should be implemented into the model and test in the framework of the 2D and 3D experiments.

  Priority: 3

  Contributors: MJ

  Means: 1 week - 5 months

- **The numerical coupling of the physics to the semi-Lagrangian dynamics**

  Description and objectives: It is known property of our model design that the current coupling of physics into the model equations is stable but just of the first order of accuracy. With the situation when the model physics plays increasingly important role for the overall model predictive skills, it is time to improve also the physics-dynamics coupling scheme. Using the advantage of the semi-Lagrangian advection scheme, one has the freedom to introduce physical tendencies at various times (like t, or t+dt) and also various places along the semi-Lagrangian trajectory (generally anywhere between origin and final points). Similar work has been already done at ECMWF (by N. Wedi), so there is a good chance to follow what had been done in the existing code. It has been shown the implemented method improving the physical coupling brought following benefits into the model:

  - second order accuracy instead of just first order one
  - if done with some care it should preserve the reached stability
  - reduces dependence on the time-step
  - reduces numerical noise

- has potential to improve mass conservation
- produces more accurate forecast
- increase memory requirements with almost no additional computer cost

Of course we are not at the same situation, since our physics completely differs from the one of IFS. During her work during summer 2004 MT showed that it should be relatively easy to introduce a similar coupling into the ALADIN (limited area) dynamics. Knowing that the new physical package ALARO-0 is going to be available soon, the right time to restart her previous work has been recognized.

Priority: 2

Contributors: MT, FV

Means: 1.5 months (1 month by LACE support)

- **Study of the spline interpolation for the semi-Lagrangian advection**

  Description and objectives: One of the potentially weak points of the semi-Lagrangian advection scheme is the interpolation of the fields to the origin point of the trajectory. The quality of the interpolation method uses to be chosen as a compromise between its acceptable accuracy and the CPU time cost required for its evaluation. In our model it has been believed that it is sufficient to use interpolatores based on 4-point cubic Lagrange interpolation. However tests with spline interpolation in the vertical have shown that a substantial improvement in conservation of ozone can be achieved with a more accurate interpolation. This has been also confirmed during the SLHD related research. As the solution to improve the current situation the general 4-point interpolator with controlled derivatives of 1^{st} and 2^{nd} order (formally equal to spline on 4 points) has been introduced between CY29T1 and CY29T2. However its performance is not as good as expected. It seems that there is still some problem in the code implementation. Since the 1D simulation results show clear superiority of this interpolation over the 4-point cubic Lagrange one and the extra cost is almost negligible, there is a clear interest to look through the 3D implementation in the model and free it from the bug. If bug is not the explanation for this surprising performance one should cleanly know the reason why the 3D performance is so different from the 1D one for this new model feature. A good tool to check the strange behavior of the existing scheme is to use 2D academic adiabatic test like the one simulating convective bubbles.

  Priority: 2

  Contributors: JM, FV

  Means: 1.5 months (1 month by LACE support)

- **TL/AD of the semi-Lagrangian scheme**

  Description and objectives: Following the increasing interest for the LAM 4DVAR assimilation system (in research mode) or for sensitivity computations at very high resolution there is strong request to have TL/AD code corresponding with the model dynamics. Since the TL/AD code of the semi-Lagrangian scheme already exists for the global models (IFS/ARPEGE) the work should entirely follow the ideas already available by the code.

  Priority: 1

  Contributors: FV

  Means: 5 months (1.5 month by Meteo-France support)

3 Coupling

- **3D diagnostic tool for coupling**

  Description and objectives: The current habit for operational applications is to increase the model resolution and consequently to reduce the computational domain. It imply for the simulated information that it starts to be more affected by the quality of LBC treatment. Logically the need for a better boundary condition becomes a necessity. The current trend is focussing to development of so called transparent LBC. With their quality being well posed there is a hope to generate less noise degrading the relevant information. Unfortunately it has been shown (by F. Voitus) that this way of coupling is very difficult to follow with the spectral model. There are several other methods how to access the existing problem (PML approach, Fourier extension,...) however none of them has ever been tested in 3D. Experience learned the NWP people that almost every new coupling method looking very promising in 1D looses it superiority over Davies coupling in 3D.

  Thus the idea is to develop 3D testing environment based on large LAM domain with embedded subdomain (with the same resolution). The performance of the two compared model on the same area would be than studied with the diagnostic tool developed specially for this purpose. The expected outcome would be also to diagnose the weaknesses of the current coupling and to propose something better with respect of known 3D behavior.

  Priority: 2

  Contributors: JM

  Means: 1.5 month (1 month by LACE support)

- **Spectral coupling**

  Description and objectives: Obtaining some positive results with the spectral coupling, the work on this subject was finished with some consequences to the code (since CY30T1). The current status is however still far from the situation to be able to use it. It is felt as loss especially with the perspective of having warning index implemented into the ARPEGE code giving us the confidence with the coupling interval. The warning index combined with the spectral coupling would be then ideal tool to secure operational forecast from the danger of information lost. In any case a further study on this subject is still required to for example define universal tuning independent to the specific meteorological situation.

  Priority: 2

  Contributors:

  Means: No action planned for 2006