Working group 2 : Dynamics, Coupling, Physics-dynamics Interface

Participants :

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Report :

The working group observed that the situation about Numerics / Dynamics research and development in ARPEGE and ALADIN has been greatly improved in the recent couple of years: the efficiency or the performance of ALADIN stages and visits in this field has significantly rised. There has been a positive feed-back between development of theoretical tools (2D and 1D models for academic situations), capability of more theoretical understanding of the behaviour of our numerical algorithms, capability of more new ideas emergence, and capability of fast testing of these new ideas. This fruitful strategy should be encouraged if we want to keep in the international research competition for the Numerics/Dynamics field.

A very positive point is that none of our topic of interest has currently an undefined status as it often occurs in past years. An undefined status means that a new idea is implemented in the full 3D model and tested for real cases, but the obtained results are so surprising that nobody knows if the implementation is bugged, or if the proposal has a scientific flaw, and in any case, nobody is able to propose a solution to progress. This status is very unconfortable because then, the process of research/development is stacked. The most typical examples of undefined status topics were: the implementation of a Radiative UBC, and the SL orographic resonance. For the first one, the research process was abandoned end 1998; if interest is set back on this point, as allowed by the better condition of the ALADIN research environment, it will probably need a significant investment to adapt the existing code to the new structure of the model. For the second point, due to the new research context, we finally managed to show that the initial proposal was not relevant, another idea was proposed, and was also shown not to be beneficial for NWP. Hence, even if the result was negative in this case, the research process was not stacked, and a clear conclusion was obtained in a short time, allowing to focus the effort on other subjects.

Generally, the effort effectively put on each individual topic matches reasonnably well with the levels of priority and scheduling established in the ALATNET Scientific and Training Program for 2000-2003. Hence, the working group did not have to rise special recommendations for increasing such or such priority. However, there is apparently a slight contradiction in the management of points 2.b and 2.c, which are intimately connected: point 2.b should be initiated rapidly since it is expected to be easier and faster to solve than the point 2.c.

The status and priority of the following points was examined:

1) Semi-Lagrangian Dynamics

a) SL constant-acceleration extrapolation:

Priority : 1

Progressing

Affected to a person

Time scale: 2 months

The work is almost finished, the advantage on the current scheme has been demonstrated, and publications are submitted. The proposed scheme remains to be evaluated in comparison with other proposed improvements (Predictor/Corrector scheme without time-extrapolation, see point 3.a).

b) Orographic resonance:

Finished

The work is finished, theoretical studies had demonstrated an advantage to a so-called SLDA (SL double averaging) treatment of the mountains compared to the current ESA (Eulerian space averaged) treatment. However, the advantage has been shown to vanish almost completely for real flows. Another approach proposed earlier and called "pseudo-SLDA" has also been shown to be intrinsically detrimental for NWP.

2) Coupling and lateral BC

a) Spectral coupling in 2D:

Priority : 1

Progressing

Affected to a person(s)

Time scale : some months (or even 1 or 2 years ?)

The topic is connected to the problem of the failure of end-1999 storms forecast by several LAMs in Europe, due to the large speed of these small-scale meteorological features (the low-pressure travelled through the coupling zone faster than the coupling frequency, and was consequently missed). This topics mixes several problems : the relevance of Davies relaxation scheme, the need of a better time-handling of the coupling data (remote applications cannot afford a high-frequency coupling, which would obvioulsly solve the problem); moreover, the whole spectral data is sent to remote sites, and it seems attractive to use the information in the interior of the domain for the coupling of large scales. For time being, alternative time-formulations to the current linear time-interpolation have been examined, but in the best case this is able to solve only a small part of the problem. The amount of work is difficult to estimate, but the spectacular forecast failure with LAMs puts a relatively high priority on the problem.

b) Coupling of Orography:

Priority : 1

Still Planned

Not affected

Time scale : 6 months

Here, the problem of the generation of noise (under the form of a constant spurious source of gravity waves) through the coupling process is addressed: if the orography of the coupling and coupled models is not the same, the flow updated by large-scale fields at lateral BC in the coupled-model will always have to adapt to the small-scale orography, thus potentially sustaining a permanent gravity wave source. This is especially true for the surface pressure field, which strongly reflects the orography. The idea to alleviate this drawback is to progressively replace the small-scale orography by the coupling-model orography when approaching the external boarder of the coupling area.

c) Coupling the tendency of the surface-pressure:

Priority : 2

Progressing

Affected to a person

Time scale : some months to a year

This topic is an improved solution for the latter point: the main part of the coupling unbalance between large-scale and LAM is in the surface-pressure field; hence, updating only the surface-pressure tendency would preserve the small-scale balanced structure of the LAM surface-pressure field. However, this is technically more difficult to implement and validate than the latter solution, and this is considered as a longer term solution. A first solution is being evaluated.

d) Coupling for the NH model:

Priority : 2

Sleeping

Not affected

Time scale : 2 months (first step)

In the current solution, NH fields are coupled to the large-scale values. This could be not necessary since these fields adapt themselves to the local flow very rapidly. A study to decide if this really matters should first be undertaken before doing further plans.

3) Time-stepping

a) New time-stepping for the Hydrostatic model:

Priority : 1

Still planned

Not affected

Time scale : some months

A new time-stepping algorithm (so-called "Predictor/Corrector" or PC scheme) has been implemented in ARPEGE by ECMWF. This scheme is potentially more stable than the classical SI scheme, especially when 2 time-level (2-TL) discretisations are used. Moreover, this algorithm allows a non-extrapolating in time 2-TL discretisation. This scheme seems attractive for solving the instabilities observed sometimes with the current operational 2-TL time-extrapolating scheme, and it should be introduced in ALADIN. It should be then evaluated on unstable situations, namely in comparison with the constant-acceleration time-extrapolation (see item 1.a). Afterwards, an objective evaluation of the efficiency of the scheme should be undertaken in view of its operational application (note that this scheme is potentially more stable, but actually more expensive than the current one).

b) New time-stepping for the Non-Hydrostatic model:

Priority : 1

Progressing

Affected to a person

Time scale : 2 years (PhD)

The NH system is by nature more unstable than the Primitive Equation one. The natural instability of this system could be solved by allowing a more implicit treatment of the equations. This can be done through iterating the above PC scheme several times. However, this rises many theoretical questions (convergence, overall efficiency, etc...) and needs a significant amount of research effort to be fully controlled.

4) NH numerics

a) Control of fast waves:

Priority : 1

Progressing

Affected to persons

Time-scale : 3 months

The complete control of fast waves by the semi-implicit (SI) scheme has been demonstrated to be possible through a change of prognostic variables. The new variables are linearly equivalent to the old ones, hence the SI algorithm is not modified at all. Some extra work remain to be done to complete the subject: input/output for data files management, update of the TL and adjoint code

b) Control of orographically induced instability:

Priority : 1

Progressing

Affected to a person

Time-scale : 3 months

Although free waves are correctly handled by the SI scheme with the above-mentionned new variables, some stationnary modes still are unstable above the orography. The introduction of the orographic forcing in the NH model should thus be studied more in detail, to try to obtain a more stable formulation. This is an open subject for which no obvious solution is foreseen so far.

c) Improvement of the Lower BC:

Priority : 1

Progressing

Affected to a person

Time-scale : 6-12 months

Several discretisations for the lower BC formulation can be chosen. Some choices could be better than the current one, especially in the formulation of the vertical Laplacian of the pressure variable at the lower BC. A slight discrepancy between stationnary orographic flows obtained with Eulerian and SL algorithms must also be studied.

5) Dynamical adaptation

Priority : 1

progressing

Affected to a person

Time-scale : 6 months (?)

Full physics dynamical adaptation experiments have revealed a divergence of some forecast fields when going towards fine-scale (i.e. 2.5 km) resolutions. The precipitation and vertical velocity are the most involved fields. This behaviour is observed identically for Hydrostatic and NH models. This problem has for the moment received no satisfactory explanation, and must be studied more in details, trying to separate firts the respective impact of dynamics and individual physical processes.

6) Radiative Upper BC

Priority : 2

Sleeping

Not affected

Time-scale : 1-2 years

A first attempt to implement a RUBC in ALADIN was abandonned after the lack of clear improvement compared to the current rigid lid in operational context. However, this failure was clearly related to the lack of a simplified test bed like the 2D vertical plane model at this time. Now this tool is available, it would be more easy to validate this alternative UBC. The problem is that most of the corresponding code has probably become obsolete due to the evolution of the system, hence this study requires a significant initial effort to re-implement this alternative algorithm.

7) Thin Layer Hypothesis

Priority : 1.5

Progressing

Affected to a person

Time-scale : some months

A formulation of the Primitive Equation system with a consistent relaxation of the Thin Layer Hypothesis (TLH) and of some other minor approximations was implemented in ARPEGE and has received a first evaluation. However, this generalization could have a more significant impact at high resolution and/or over tropical areas. Hence it would be wishable to validate the ALADIN version, which has been coded as well, and to define relevant tests to objectively evaluate the benefit which can be expected from this formulation (so far no clear advantage has been found on randomly chosen test cases for ARPEGE).

8) Diabatism in NH system

Priority : 2

Still planned

Time-scale : some months

This topics covers in fact two separate issues: how to introduce the dry diabatism in the NH dynamics, and how to make consistent the introduction of the phase-change diabatism with the dry formulation. For the first point, a simple formulation with a projection of diabatic sources on hydrostatic modes has been chosen from the origin of the NH model: this approach allows to keep the diabatism as it is formulated in the hydrostatic version. It had been demonstrated that this approach was valid for resolutions in the kilometric range, and for meshs with a small aspect ratio. For the second point, a sequential approach as in the hydrostatic version has also been chosen. However, the NH version has a coupling of pressure and thermodynamical equations, and it is not certains if this sequential approach is the best one, because both phase-changes and hydrostatic adjustment process have very small time-scales. Some alternative approaches could then be defined and tested. The first question to be answered should logically be is this problem important at our scales ? . For this a short set of well-chosen test should give an idea of the answer and allow to decide if more effort should be put on this research topic.