Research plan of the LACE working group "Dynamics and coupling" for the year 2003

(proposal to the LACE Steering Committee)

February 28, 2003

Proposed projects:

I. Non-hydrostatic dynamics
II. Dynamics – other topics
III. Coupling

Legend:

- *Risk evaluation* wants to qualify the fact that for topics needing basic research the completion of task may not be ensured even if a lot of efforts addected, in contrast to validation or experimentation that always give a result; 3 – risky, 2 – at least partial results are expected, 1 – no risk.
- *Future work* shows the possible directions of further research or development foreseen for time period after the end of 2003.
- Computer facilities available "in situ" are always sufficient for the realization of planned work.

I. Non-hydrostatic dynamics

Policy aspects: With the refinement of resolved scales in numerical models, the relaxation of the hydrostatic approximation through the use of nonhydrostatic fully-compressible system emerges as an attractive and urgent solution. The aim for NWP models should be to achieve the relaxation while keeping the same degree of efficiency as the former HPE system.

On the platform of ALADIN model, an NH version has been developed (Bubnová et al., 1995) based on the fully compressible Euler equation system with the Laprise (hydrostatic pressure based) vertical coordinate (Laprise, 1992). An unstable behaviour was detected for the EE system in the pure SI time-discretization, and this problem was solved through the iteration of a part of the NL residual terms (current option LPC_OLD). A fully iterative time scheme called predictor/corrector scheme is presently under development for NH dynamics (Vivoda, ALATNET PhD study) and is expected to be fully harmonized with the iterative scheme of IFS.

It was shown that better stability properties may be reached by a change of prognostic variables. Several propositions for the two additional NH variables, the variable representing vertical divergence and the variable for pressure departure, were implemented and tested. Further tests and new ideas implementation are supposed to advance this work.

The lack of accuracy was detected in SL advection scheme over mountain areas and the problem was solved by the use of vertical velocity instead of vertical divergence in grid-point calculations (Smith, ALATNET postdoc study). The question whether a similar effect could be obtained by applying a less complicated and demanding method has arisen and is expected to be answered.

Further improvement of stability and accuracy of ALADIN-NH dynamics is expected and demanded, especially after the decision made at Météo-France that ALADIN-NH dynamics has become a part of AROME project.

Link to the ALADIN RP: The main objective of the proposed project is to advance research and development of the ALADIN code in high-priority topics mentioned in the ALADIN Research Plan.

ALADIN interactions: The cooperation within the ALADIN-NH community is well established, with the scientific leadership of Pierre Bénard (MF). In 2003, the work in the frame of LACE will be concentrated in Prague with possible e-mail exchange with people who will not be present there.

ALADIN platform: The designed developments follow recent progress of ALADIN NH dynamics. Therefore an advanced version of ALADIN code has to be used for testing and validation as well as for the research. A compulsory cycle is CY25T1/AL25T1 (P/C scheme), a more recent ALADIN version (CY25T2/AL25T2 with w, d_4 as prognostic variables, P/C scheme bugfix and better sponge implementation) is recommended. Therefore the first technical conditions necessary for a successful project completion are new powerful computer establishment at CHMI and the new ALADIN cycle porting to Prague (M.Janoušek, CHMI).

Total manpower: 17 person x months, 3 months of stay in Prague

Main objectives and means (separated according to topics):

I.1 Iterative schemes

Current status: The 2tl P/C (predictor/corrector) scheme has been developed and implemented in the NH model recently (Jozef Vivoda – ALATNET PhD study). Moreover, several options have been realized (extrapolating and non-extrapolating scheme with trajectory recomputations or without it, possibly with decentering of first or pseudo-second order). This work is to be finished and validated.

Planned work (outputs):

- code debugging and cleaning
- rationalization and harmonization with IFS (merging of 2tl P/C scheme with trajectory recomputation with 2tl P/C scheme developed in ECMWF for hydrostatic model, clear and unique control of the iteration ...)
- documentation writing (scientific and technical guide to the current code)
- validation and testing to get the comparison between different iterative schemes and with 3tl SI scheme (2D vertical plane model, 3D trapped lee wave test, ALPIA academic 3D case, real case study)

Risk evaluation: 2

Future work: A logical enhancement of this task is the extension of P/C scheme to 3tl framework that will enable the scientific validation of 2tl P/C scheme (a task appropriate to a person with advanced knowledge of the ARPEGE/ALADIN code, not affected to a person).

Means:

- 8 person x months
- no financial support asked

Calendar: – Jozef Vivoda (SHMI), February - September 2003, ALATNET stay in Prague

I.2 Choice of additional NH prognostic variables

Current status: The choice of prognostic variables was shown to play an essential role for the stability of temporal schemes. Several formulations of the two additional NH prognostic variables were proposed (denoted $w, d_0, \ldots d_5$ for the variable derived from vertical velocity/divergence, and $P_0, \ldots P_2$ for the variable derived from the pressure departure). Then the linear analysis of the stability of different sets of basic equations was performed, the proposed variables were introduced to the NH model and tested in 2D vertical plane model.

Planned work (outputs):

- validation and testing of combinations of different choices of prognostic variables with different time-stepping schemes (variants of 2tl P/C scheme, 3tl scheme)
- an optimal choice of the additional NH variables; or the elimination of less advantageous or redundant formulations to get a reasonable amount of options

Risk evaluation: 1

Future work:

- boundary conditions - sponge and coupling with respect to distinct choices of prognostic variables (research, implementation and testing)

Means:

- 1 person x month
- LACE stay in Prague

Calendar: – Jan Mašek (SHMI), November 2003, Prague

I.3 Bottom boundary condition

Current status: The SL advection scheme appeared to introduce severe defects in the region above mountains (chimney effect). The cause has been traced to the lack of an effective free-slip lower boundary condition (Christopher Smith – ALATNET postdoc study). There appeared several ideas about possible cures of this problem.

Planned work (outputs):

- diagnostical formulation of the BBC in SL scheme (research, implementation, validation and testing in 2D vertical plane model)
- a well-founded decision whether it is really needed to advect vertical wind w or not

- the use of w instead of vertical divergence "d" as a prognostic variable (accomplished by C.Smith for variables $d_0, \ldots, d_2$) needs to be adapted to other proposed variables $d_3, \ldots, d_5$ – task completion (search for a solution, implementation and testing); depends on the answer to the previous item
- academic experiments to understand more the mechanism of chimneys origin; the goal is to find the term in basic equations responsible for spurious effects, to find out the relation with the timestep, is the phenomena purely linear ?; Z-term problem (instability caused by the advection of derivatives)

Risk evaluation: 3

Future work:

- coupling of w instead of "d" variable

Means:

- 6 person x months of local work
- 2 person x months LACE stay in Prague

Calendar: – Petra Smolíková (CHMI), spring 2003 (4 months), Prague
– Radmila Brožková (CHMI), spring 2003, 1 month in Toulouse, 2 weeks in Prague
– Jan Mašek (SHMI), May 2003 (1 month) + October 2003 (1 month), LACE stays in Prague
– Jozef Vivoda (SHMI), autumn 2003 (2 weeks), Bratislava

II. Dynamics - other topics

Policy aspects: Besides NH dynamics there are other topics important for the model ability to find an appropriate solution in very high horizontal resolutions.

Finer resolution models being able to describe more physical damping processes (turbulence, molecular dissipation) by themselves, the remaining part related to the sub-grid processes becomes smaller. The role of numerical damping thus decreases with increasing resolution. On the other hand the importance of physical damping processes grows with increasing horizontal resolution. As a consequence the need of a nonlinear formulation of horizontal diffusion becomes a burning problem. A new NL diffusion scheme making use of the diffusive properties of the SL advection scheme is presently under development (Váňa, PhD study) and is expected to be finished this year.

At fine scale models a good radiative upper boundary condition is further needed to radiate out of the model domain most of the energy of waves hitting the top boundary and avoid its reflection back. Recently published analyses for hydrostatic and NH sets of equations will become a starting point for the research in ALADIN framework.

The implementation of an iterative (predictor/corrector) temporal scheme in ALADIN-NH model version asks for a study of the physics-dynamics interface with the goal to find a solution convenient for this approach to the time-stepping procedure without being superfluously demanding. The study of interaction between physics and NH dynamics and its consequence to stability properties of the model may further advance the work.

Link to the ALADIN RP: The proposed topics match with the ALADIN Research Plan high (II.1) and medium (II.2,3) priority objectives.

ALADIN interactions: The work is planned to be performed in Prague and Toulouse. For physics-dynamics interface as a boundary topic there is further development to be done by the LACE working group "Physics"; see the research plan of this group for the details. Eventual problems will be disscussed by e-mail to avoid overlaps of the work of the particular contributors.

ALADIN platform: mentioned separatelly according to topics

Total manpower: 11.25 person x months, 1 month of stay in Prague

Main objectives and means (separated according to topics):

II.1 Horizontal diffusion

Current status: A nonlinear horizontal diffusion based on the diffusive properties of SL interpolators has been developed (F.Váňa - ALADIN PhD study).

Planned work (outputs):

- phasing of the development to the last cycle (CY25T2/AL25T2)
- tunning to get the optimal parameters of the diffusive scheme
- validation in very high resolution (2,5 km) - academic experiments with ALPIA case, real case study
- extension to NH dynamics

Risk evaluation: 1

Future work:

- implementation of nonlinear spectral horizontal diffusion (by a combination of spectrally diffused fields in GP space)
- careful validation for the humidity field, implementation of the possibility to avoid spectral transformation of humidity and use only GP horizontal diffusion of this field

Means:

- 8 person x months
- no financial support asked

ALADIN platform: The SL horizontal diffusion scheme has been developed on AL08 and then successively phased to newer cycles. Hence the work may be accomplished on almost any ALADIN cycle, preferably at least AL15. The modification is supposed to enter the official cycle CY26/AL26 in spring 2003.

Calendar:

- Filip Váňa (CHMI), March/April 2003 (6 weeks) in Toulouse – MF stay, autumn 2003 (4.5 months) in Prague
- Rok Glavač-Šah (Slovenian student), February/March 2003 (2 months), Prague - LACE stay conveyed to 2002

II.2 Radiative upper boundary condition

Current status: 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 the influence of the modification of phase speed of the waves caused by a semi-implicit 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.

Planned work (outputs):

- literature retrieval (news in 2002)
- implementation to 2D vertical plane version of ALADIN
- merging with P/C schemes to get a stable solution
- 2D and idealized 3D experiments (SCANIA case)

Risk evaluation: 3

Means:

- 2 person x months
- no financial support asked

ALADIN platform: To be able to perform 2D experiments the most recent ALADIN cycle CY25T2/AL25T2 is recommended (this cycle offers better implementation of sponge). At least CY25T1/AL25T1 is compulsory for the merge with P/C scheme.

Calendar: – Martin Janoušek (CHMI), autumn 2003, 6 weeks in Toulouse - MAE stay, 2 weeks in Prague

II.3 Physics/dynamics interface

Current status: The work hasn't started yet.

Planned work (outputs):

- the use of physics within P/C scheme (validation)
- the impact of dynamical forcing to the stability of the NH model (validation)

Risk evaluation: 2

Future work:

- time-stepping aspects for AROME's physics

Means:

- 1 person x month, LACE stay in Prague
- 1 person x week, local work

ALADIN platform: The lowest model cycle which can be used to accomplish this task is CY25T1/AL25T1 (P/C scheme).

Calendar: – Martina Tudor (DHMZ), June 2003 (1 month), LACE stay in Prague
– Radmila Brožková (CHMI), June 2003, 1 week for supervision

III. Coupling

Policy aspects: The research in this area has recovered higher intensity after the failure of the ALADIN model in December 1999. Two fast-propagating storms correctly forcasted by the global model ARPEGE were not captured at the lateral boundaries of the ALADIN-FRANCE domain. A serie of case studies at very high resolution and a search for more convenient solution have started.

First the impact of different coupling strategies without the change in coupling implementation was examined (wider coupling zone, enhanced coupling frequency, higher order time interpolation (Dvořák, 2000), combinations of HY and NH dynamics in leading and nested models, orography resolution (Stadlbacher, 2001)).

Then new coupling methods were proposed such as spectral coupling or amplitudes and phase-angles interpolation. A diagnostic method for detection of cases in which the signal from the leading model is of great importance and could be possibly missed by the nested model is under development (Termonia, 2003). These methods are expected to be further developed and tested in the year 2003.

Link to the ALADIN RP: The project deals with high and medium priority objectives (III.1,2) of the ALADIN Research Plan. Two additional topics (III.3,4) are proposed with the aim to discover possible benefits and design the strategy for future research.

ALADIN interactions: The research is supposed to gather in Ljubljana and Budapest, tests of the ARPEGE/ALADIN coupling behaviour will be performed in Zagreb. Close cooperation is expected between the project contributors and partners in Belgium (Piet Termonia, Chantal Moussy). Recent progress and further strategy of research and development will be discussed in February in Ljubljana during the "Mini coupling workshop".

ALADIN platform: Two of the proposed topics (III.1,2) follow recent developments in the ALADIN code. The availability of recent ALADIN libraries (CY25T2/AL25T2) is hence a necessary condition for their successful completion. The other two topics (III.3,4) are not dependent on any novelty and may be accomplished in any ALADIN cycle.

Total manpower: 3.5 person x months (+6 months - contribution of Raluca Radu from Rumania, work accomplished at LACE countries), 1 week workshop

Main objectives and means (separated according to topics):

III.1 Spectral coupling

Current status: Spectral coupling code has been implemented both in 1D model and in 3D ALADIN in a not too clean way, but the code is capable for tests even in multi-processor environment. The study of the influence of spectral coupling frequency has been finished. 1D tests proved that spectral coupling at every timestep combined with gridpoint Davies relaxation gives rise to a strong dipole (large scale signal is not advected with wind but it diminishes at one place and recreates at another one). Less frequent spectral coupling causes jumps in the solution. This behaviour was confirmed by 3D tests on Christmas storm.

Planned work (outputs):

- cleaning of the code, phasing to the main cycle and validation
- tuning by changing the transition function (that determines the ratio between large and small scale solution for each wave number) and its evolution in time
- tests of the interaction between spectral coupling and the Davies relaxation scheme, and design of an optimal coupling strategy

Risk evaluation: 1

Means:

- 5 person x months
- no financial support asked

Calendar: – Raluca Radu, 4 months, ALATNET stay in Ljubljana
– Gregor Gregorič (HMIS), 2 weeks for supervision
– Jure Jerman (HMIS), 2 weeks for supervision

III.2 Surface pressure tendency coupling

Current status: The code developed by Tamas Szabo has been ported to the last library AL25T2 by Jean-Marc Audoin and Chantal Moussy. So far some 3D tests have been performed.

Planned work (outputs):

- 2D and further 3D tests
- tests evaluation, potential benefits detection and furher strategy design

Risk evaluation: 2

Means:

- 2.5 person x months

- no financial support asked

Calendar: – Raluca Radu, 2 months, ALATNET stay in Budapest
– Gábor Radnóti (HMS), 2 weeks for supervision

III.3 Two-time nesting

Current status: work hasn't started yet

Planned work (outputs):

- tests of the ALADIN model behaviour in relation to the coupling frequency in both nesting steps (with the use of operational applications ALADIN-LACE and ALADIN-HR at DHMZ)
- tests evaluation and further strategy design

Risk evaluation: 2

Means:

- 1 person x months
- no financial support asked

Calendar:

– Stjepan Ivatek-Šahdan (DHMZ), March/April 2003 (1 month), Zagreb

III.4 Coupling files initialization

Current status: Some tests of the model behaviour according to the DFI initialization of every LBC field were made few years ago (V. Ivanovič). It was remarked that DFI treatment is very time-consuming and without the beneficial impact to the forecast.

Planned work (outputs):

- further tests of the ALADIN model behaviour
- tests evaluation and further strategy design

Risk evaluation: 2

Means:

- 1 person x months
- no financial support asked

Calendar: – Dijana Klarič (DHMZ), April 2003, Zagreb

III.5 Mini coupling workshop

The main aim of the workshop is that people who are working on coupling problems inside ALADIN (LACE) community gather together, exchange their knowledge, do some common work and discuss about future plans.

Planned work (outputs):

- presentations about recent progress
- common work, presentation of results
- discussion about future work

Participants (from LACE countries):

- Klaus Stadlbacher (ZAMG)
- Stjepan Ivatek-Šahdan, Martina Tudor (DHMZ)
- Gábor Radnoti (HMS)
- Petra Smolíková (CHMI)
- Gregor Gregorič, Jure Jerman, Neva Pristov (HMIS)

Means:

- LACE support to the WGL mission to this workshop (2 days)

Calendar: 17 - 21 February 2003, Ljubljana