LACE Working Group for Dynamics & Coupling: Research progress summary from 2003

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(using materials prepared by Petra Smolíková)
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Contents

1 Introduction

The aim of this paper is to summarise the research in the fields of dynamics and coupling within the framework of RC LACE. It tries to follow the original topics given by the research plan for the 2003 even when some of them has been continuously transformed during the ongoing research. However when it seems to be indispensable new subjects are appearing not defined in the original research plan.

2 Progress report

2.1 Non-hydrostatic dynamics

The research reported in this paragraph is the example of the real joint research of a group of people. (Most probably it is the only research team activity within the LACE community.) This group exhibited the potential to dynamically extend their activity in an area at which some unexpected problem is detected during the research process. This flexibility is extremely beneficial to the overall results reached by the all NH group. The plan for 2003 was expecting to finalise the stable and accurate NH dynamics ready to serve as the dynamics core for the future AROME project. Although most of the research subjects have been fulfilled there are still few remaining problems which would require some further work to be satisfactory solved.

• Iterative schemes

Description and objectives: The 2TL P/C (predictor/corrector) scheme has been developed and implemented in the NH model recently. Several options inside the scheme have been realized (extrapolating and non-extrapolating scheme with trajectory recomputation or without it, possibly with decentering of first or pseudo-second order) that have to be further studied and harmonised with the data-flow structure of the model.

Planned actions:

1. code debugging and cleaning
2. rationalisation and harmonisation with IFS (merging of 2TL P/C scheme trajectory recomputation with 2TL P/C scheme developed in ECMWF for hydrostatic model, clear and unique control of the iteration. . .)
3. documentation writing (scientific and technical guide to the current code)
4. 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)

Status: Various aspects of the P/C scheme were studied theoretically by stability analysis (TL 1D advection, SW 1D model, analysis of Rossby mode - problem formulation, the effect of SITRA option, etc.) The technical documentation for the P/C scheme has been issued helping the other people to work with the P/C scheme. The various documentation has been already released or are in process of preparation. The harmonisation with IFS was done during the two weeks stay in Meteo-France. (Afterwards the P/C scheme was removed from IFS with harming influence to the P/C scheme in ALADIN. Hence another effort had to be spent to bring P/C scheme back to life in AL27.) Currently 2TL P/C scheme is available for NH and hydrostatic dynamics with semi-Lagrangian advection. Some cleaning is still expected which is planned for the 2004. The validity of the P/C scheme was tested on the Lothar storm case.

Contributors: Jozef Vivoda, Martina Tudor

Effort: JV - 8 months at Prague (ALATNET stay), MT - 2 weeks at Toulouse (Météo-France phasing)

Documentation: J. Vivoda - technical documentation, various ALATNET reports, presentation during the 13th ALADIN seminar, GMV/GFL documentation

Code availability: AL25t2, AL27 and higher cycles

• Choice of the additional NH prognostic variable

Description and objectives: 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,. . . , d_5 for the variable derived from vertical velocity/divergence, and P_0, P_1, P_2 for the variable derived from the pressure departure). With all the different prognostics variables combinations the linear analysis of the stability was performed as well as the testing in 2D vertical plane model. The aim of planned work was mainly to find the best performing (the most stable and accurate) combination of the NH prognostic variables for the ALADIN (AROME) NH dynamics.

Planned actions:

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

Status: The choice of the prognostic NH prognostic variables was implied by several different studies with the NH dynamics. The chosen additional NH prognostic variables are the couple of d_4 and P_2. However there is still remaining problem of the d_4 (d_3) which are performing a better when being advected in the form of w. This can be cleanly exhibited (and studied) when performing the bubble test where the performance of the ω advection is superior to the advection of d_3 or d_4 only. Since this tricky formulation with conversion of ”d” variable into ω in every timestep is not really favourable for the operational purposes, some effort was invested to further improve the performance of the pure d_4 (d_3) variable(s). Although this problem haven’t been solved yet, the first results seems to be promising. Most probably this problem could be potentially cured by some better discretization in the SL model formulation. The cleaning of the other NH prognostic variables was not performed yet. It is scheduled for the summer 2004.

Contributors: different contributors (choice of the prognostic variable), Ján Mašek (residual problem in d_4 (d_3) performance)

Effort: 1 month (LACE stay at Prague)

Documentation: J. Mašek - Residual problems in ALADIN-NH Dynamical Core

• Bottom boundary condition

Description and objectives: The SL advection scheme appeared to introduce severe defects in the region above mountains (so called chimney effect). The cause has been traced to the lack of an effective free-slip lower boundary condition. Several ideas appeared about possible cures of this problem.

Planned actions:

1. diagnostic formulation of the BBC in SL scheme (research, implementation, validation and testing in 2D vertical plane model)
2. a well-founded decision whether it is really needed to advect vertical wind ω or not
3. the use of ω instead of vertical divergence d as a prognostic variable (accomplished by C. Smith for variables d_0,. . . , d_2) needs to be adapted to other proposed variables d_3,. . . , d_5 (dependent on the answers to the previous items)
4. 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)

Status: The diagnostic formulation of the BBC in SL scheme has been implemented and tested in simple academic 2D context (potential flow, NL NH regime). It revealed as a promising method since the numerical noise created in SL scheme above mountains (chimney effect) was suppressed (work of P.

Smolíková and R. Brožková). This work was further phased and validated to the AL26 to be available during the AL27 phasing (R. Brožková and G. Hello). Hence to avoid the so called chimney, there is no need for the advection of ω. However the availability of the ω advection was extended to d_3 and d_4 variables (for particular option), thus this solution can be studied with the best NH prognostic variable combination (work of J. Vivoda). The further diagnostics of the chimney origin clarified that the so called Z-term is not responsible for it (work of J. Mašek). It was however discovered that there is another source of the chimney effect (detected in all the possible NH configurations including the Eulerian advection and advection of ω) which is linked to the horizontal diffusion treatment (work of J. Mašek, P. Benárd and R. Brožková).

Contributors: P. Smolíková (4 months), R. Brožková (3 months), J. Mašek (2 months), J. Vivoda, P. Benárd

Effort: total 9 months and 3 weeks for LACE people (PS - 4 months, RB - 3 months and 2 weeks, JM - 2 months, JV - 1 week) from which are: 2 months (WGL), 2 months (LACE stay at Prague), 2 weeks (Météo-France stay at Toulouse)

Documentation: P. Smolíková - The use of diagnostic BBC in SL scheme,
J. Mašek - Reformulation of Bottom Boundary Condition for Term $\partial\, \tilde{}p/\partial\pi$,
J. Mašek - Residual problems in ALADIN-NH Dynamical Core

Code availability: Diagnostic BBC - AL25t2, AL26, AL27 and higher cycles; ω advection with d_3 and d_4 - AL25t2 only

Newly appeared topic

• 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 parametrization. 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. However the exact treatment would introduce an implication to the code (additional source terms of heating appearing in the continuity equation would imply modifications of the equation for the surface pressure and the diagnostic equation for vertical velocity) which creates some degrees of freedom for the code. Thus some special care has to be paid when the exact solution would be implemented.

Actions:

1. understand the problem of hydrostatic adjustment and try to introduce consistently the exact form of diabatism
2. estimate the portion of the wave energy triggered by heating when the exact solution is applied

Status: In the framework of the 2D academic experiments with no physics (except the introduced source of heating) the performance of the hydrostatic adjustment and the exact implementation of the diabatism was studied. Performed experiments gave an indication that the differences between the two approaches are negligible after a very short period. Hence it seems to be promising starting point for the next efforts which could be put on coding of 3D exact version and to test it during the real case experiment.

Contributors: Alena Trojáková, Pierre Bénard

Effort: 1.5 month (MAE stay at Toulouse)

Documentation: A. Trojáková - Diabatic forcing in fully compressible model

Code availability: CY26t1

2.2 Dynamics - other topics

The topic listed in this section are mainly work of individual people or work related to such work. Since the involved people mostly fulfilled their effort to the planned work, the progress is reflecting the amount of the technical and scientific problems which one had to face during his/her working on the subject.

• Semi-Lagrangian horizontal diffusion

Description and objectives: A nonlinear horizontal diffusion based on the diffusive properties of SL interpolatores was developed for the ALADIN (F. Váňa, ALADIN PhD study). The design of the scheme has to be defined, the proposed tunable parameters justified and tuned to their optimal values and some further tests have to be done in order to verify the possible benefits of the scheme.

Planned actions:

1. phasing of the development to the last cycle
2. tuning to get the optimal parameters of the diffusive scheme
3. validation in very high resolution (2.5 km) - academic experiments with the ALPIA experiment, real case studies
4. extension to NH dynamics

Status: The optimal values of the tunable parameters were defined from the four resolution of the ALADIN/LACE domain. Accordingly the SLHD scheme was extended to the NH and the proposed tunable parameters were justified with the NH ALPIA (5 km and 2.5 km) adiabatic experiment. In all the experiments the SLHD scheme was found to perform at least with a similar accuracy as the reference spectral horizontal diffusion if not in a better way (work of R. Glavač-Šah and F. Váňa). The SLHD scheme has been tested for several cases when the operational forecast produced an too deep meso-cyclone or other unrealistic small scale feature. In the most of the cases the use of the SLHD scheme improved the operational forecast (Trafalgar case, Adriatic storm, Black sea storm,. . .) (work of F. Váňa and A. Simon). At this moment the SLHD scheme has been ported to the AL26 to be available during the AL27 phasing. Before arriving the official source, the scheme has been technically redesigned to be in agreement of the code logical structure and the other changes in the SL dynamics. The design of the interaction with P/C scheme had to be solved as well (work of F. Váňa and K. Yessad).

Contributors: Filip Váňa, Rok Glavač-Šah, Karim Yessad, André Simon

Effort: 6 months and two weeks for LACE people from which were: 3 months (Slovenia LACE contribution to Prague stays in 2002), 1.5 month (Météo-France stay at Toulouse) and 2 weeks (ALATNET stay at Toulouse)

Documentation: R. Glavač-Šah- Spectral diffusion and Semi Lagrangian horizontal diffusion scheme,
F. Váňa - Semi-Lagrangeovské advektivni schéma s kontrolovanou difuzivitou - alternativni formulace nelineárn i horizontálni difuze v numerickich predpovednich modelech (PhD thesis in Czech with extended English and French summary),
A. Simon and F. Váňa - False mesoscale cyclogenesis in the ALADIN model - Sensitivity study on initial conditions, physical parametrization and horizontal diffusion (ALADIN Newsletter 24)

Code availability: AL25t1, AL26 and higher cycles

• 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 of the modification of 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.

Planned actions:

1. literature retrieval
2. implementation to 2D vertical plane version of ALADIN
3. merging with P/C scheme to get a stable solution
4. 2D and 3D experiments (SCANIA case)

Status: The work has started. Set of equation was analysed. Guidelines for the future work has been defined. The research haven't arrived to its experimental part yet.

Contributors: Martin Janoušek

Effort: 1.5 month (MAE stay at Toulouse)

• Physics / dynamics interface

Description and objectives: Main purpose of this work was to enable usage of the physical package with the P/C iterative scheme. All the possible options should have been verified allowed by this scheme.

Planned actions:

1. usage of physics within the P/C scheme (validation)
2. validation of the diabatic forcing impact to the stability of the NH model

Status: The P/C scheme was extended by the possibility to call the physical package. Model was afterwards tested on the ALPIA case with the 10, 5 and 2.5 km resolutions. Hydrostatic 2TLSISL, NH 2TLSISL and NH P/C scheme model configurations were used, with and without physics. Different extrapolation scheme were tested as well: Robert, LSETTLS and non-extrapolating scheme (with the P/C scheme only). The observed differences with respect to the model configuration or the extrapolated scheme has been found, but no significant conclusion can be currently derived from it. From the NH configurations the P/C scheme offered the most stable performance with respect to the length of the model timestep.

Contributors: Martina Tudor, Jozef Vivoda, Radmila Brožková

Effort: total 2 months (MT - 1.5 month, RB & JV - 1 week of supervision each) from which was 1 month LACE stay at Prague

Documentation: M. Tudor - Physics - Dynamics Interface for Predictor - Corrector Scheme

Code availability: AL25t2, AL27 and higher cycles

Newly appeared topic:

• New formulation of spectral horizontal diffusion when SLHD

Description and objectives: When the SLHD scheme is activated some remaining spectral diffusion is still kept in the model. It is there mainly for two reasons: first to simulate the vertical profile of the horizontal diffusion which has the increasing power toward the top of the atmosphere, second to control the noise generated by the orography in the field of vorticity and divergence. The aim of this research work was to separate the two functions of the spectral diffusion into a two independent spectral diffusion schemes. This technical arrangement would allow fairly easier tuning and control of the damping inside the model than it was the case before.

Planned actions:

1. split the spectral horizontal diffusion into two when SLHD is activated (i.e. add new spectral diffusion keeping one of the supporting roles)

2. validate the new treatment and phase it into the latest model cycle with extension to the global model

Status: The proposed arrangement was coded and tested with the AL25t1. The performance was similar to the previous arrangement while the tuning was trivial when the operational setting for spectral horizontal diffusion are known. The new modifications has been ported into the AL27/CY27 based source to enter the AL28T1/CY28T1 official source. The availability in the global model has been revisited. However during the preparation for the operational usage of the SLHD (for the MFSTEP domain), too strong diffusion near the surface has been detected. Although some first proposal to fixing the problem already exists, it would require some additional diagnostics in order to understood the SLHD scheme performance. Possibly some presumptions justified in the framework of the academic test would have to be revisited.

Contributors: Filip Váňa, Karim Yessad, Mária Derková

Effort: total 2 months and 2 weeks for LACE people: 2 months (WGL), 1 week (Météo-France stay at Toulouse), 1 week (MFSTEP grant in Prague)

Documentation: K. Yessad - SL scheme and horizontal diffusion code documentation relevant to CY28T1

Code availability: AL25t1, AL28T1/CY28T1

2.3 Coupling

Contrary to the LACE research in dynamics the coupling relevant research was fulfilled mainly in the relations of the ALATNET PhD studies. There was not much research completely independent to some of the ALATNET studies in the field of coupling. This creates a potential danger for the future when the ALATNET resources will gone.

• Spectral coupling

Description and objectives: 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. 1D tests proved that spectral coupling at every timestep combined with gridpoint Davies relaxation gives too strong large scale forcing. Then the coupled model is not able develop ”its own solution”. It was confirmed by 3D tests on Christmas storm.

Planned actions:

1. cleaning of the code, phasing to the main cycle and validation
2. tuning by spectral coupling frequency and possibly by changing relaxation coefficients
3. tests of the interaction between spectral coupling and the Davies relaxation scheme, design of an optimal coupling strategy

Status: The spectral coupling is available from the AL26 in the main code. It has been tuned for some particular cases (including 3D one with the 1999 Christmas storm). Some new ideas has been introduced during the ongoing work like the increase of the wave number interval where the spectral coupling is applied or application of some time relaxation of the transition function. Finally the strategy for the optimal coupling design has been defined by P. Thermonia. This effectively means the end of the diagnostic study in this area. However some further case studies would be potentially useful to finish this subject in order to prove that the scheme does not too much destroy meso-scale features for cases when the model provides extra meso-scale information with respect to the coupling model.

Contributors: Raluca Radu, Gregor Gregorič, Jure Jerman

Effort: total 5 months for LACE people: (RR - 4 months ALATNET PhD study at Ljubljana, GG & JJ - two weeks each)

Documentation: R. Radu - various ALATNET reports

Code availability: AL26 and higher

• Surface pressure tendency coupling

Description and objectives: The code developed by Tamas Szabo has been ported to the last library AL25T2 by Jean-Marc Audoin. So far 2D test have been performed.

Planned actions:

1. further 2D and afterwards 3D tests
2. tests evaluation, potential benefits detection and further strategy design

Status: Nothing done

• Two-time nesting

Description and objectives: The aim of this study was to compare the real case performance of the nested models driven by the LBC with different coupling interval.

Planned actions:

1. tests of the ALADIN model behavior in relation to the coupling frequency in both nesting steps
2. tests evaluation and further strategy design

Status: The experiment was performed on operational Croatian domain. As driving model the ALADIN/LACE was used. The nested models were driven by 3 hours and 1 hour coupling intervals LBC. In both case the ability to further improve forecast (surface pressure) from the leading model has been detected. The model coupled with 1 hour LBC frequency was found performing better forecast than the one with 3 hours frequency, especially for some dramatic weather event cases.

Contributors: Stjepan Ivatek-Šahdan

Effort: 1 month

Documentation: S. Ivatek-Šahdan - Coupling frequency - two time nesting

• Coupling files initialization

Description and objectives: Some tests of the model behavior according to the DFI initialization of every LBC field were made few years ago (V. Ivanovici). That time it was concluded that DFI treatment is very time-consuming and without the beneficial impact to the forecast. With the increasing model resolution there was the plan to revisit once again this idea more carefully.

Planned actions:

1. further tests of the ALADIN model behavior
2. tests evaluation and further strategy design

Status: Nothing done

• Mini coupling workshop

Descriptions and objectives: 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 actions:

1. presentations about recent progress
2. common work
3. discussion about future work

Status: The Mini-coupling workshop was successfully held in Ljubljana during February 17-21, 2003. The first day was devoted to presentations about recent progress, the common work was accomplished in several groups during the following three days and the achieved results were presented last day. The workshop was attended by 13 participants. It was agreed that such a structure of a workshop is efficient and this kind of workshop can bring new ideas and accelerate the work on given subjects.

Documentation: http://www.rzs-hm.si/alatnetseminar/mcw.html

Participants: Klaus Stadlbacher, Alexander Beck, Chantal Moussy, Piet Termonia, Martina Tudor, Stjepan Ivatek-Šahdan, Petra Smolíkova, Jean-Marc Audoin, Gábor Rádnoti, Raluca Radu, Gregor Gregorič, Jure Jerman, Neva Pristov

Topic not in the plane for 2003

• Strategy for high resolution coupling

Description and objectives: In the framework of the PhD study with the subject: ”Systematic qualitative evaluation of high-resolution non-hydrostatic model” there was some effort spend on defining strategy for the coupling of high resolution models. Mainly the sensitivity to the resolution and dynamics (hydrostatic or NH) of the leading model and also the size of the nested model have been studied during this ALATNET PhD work.

Planned actions:

1. testing of a sensitivity to the nested domain size
2. testing of a sensitivity to the coupling file resolution

Status: The sensitivity of the LBC files resolution was found very important, sometimes even more important than the kind of leading model dynamics. The size of the nested domain size is also playing some role for the simulated results.

Contributors: Klaus Stadlbacher

Effort: ALATNET PhD study in Ljubljana

Documentation: K. Stadlbacher - various ALATNET reports, presentation during the 13th ALADIN seminar.