LACE Project proposal

GENERAL INFO

Project name: ***Toward an operational implementation of the NH dynamics***

Responsible person: ***Filip Váňa***

Institution responsible for the project: ***CHMI***

Abstract: *The aim of this project is to deliver stable, accurate and efficient NH dynamics, ready for operational implementation in the model Aladin. With such an objection the special attention should be paid not only to the NH dynamics itself but also to its interactions with the other model components like physics, data assimilation or lateral boundary condition treatment within the complex full operational system.*

Keywords: ***Non-hydrostatic (NH) dynamics, model resolution, vertical finite elements (VFE), lateral boundary coupling (LBC), physics-dynamics coupling***

BACKGROUND

Since more than 10 years ago the Aladin model hydrostatic dynamics can be optionally extended to fully elastic NH one. This mainly research alternative significantly evolved to the current state possessing comparable stability and efficiency with respect to the operational hydrostatic dynamics. With the interest to increase a resolution of operational models toward the kilometric scale, an operational exploitation of the NH dynamics should be also considered.

The present state of the NH dynamics seems to deliver acceptable results in adiabatic academic tests, although even there some minor problems are detected. The main limitation for the potential operational use is however seen in the fact that the complex validation of the NH dynamics with respect to the verified and trustable hydrostatic dynamics in the full model is missing. Like that any potential switch to NH dynamics may be questioned in terms of benefits or stability for the whole operational application.

Finally the NH dynamics code is significantly evolving due to the current joint initiative of Météo-France and ECMWF for its adaptation (and further development) for the global geometry. It is felt as a pity (for both sides) that the original NH code developers are not able to contribute to this action.

From all the above reasons plus the fact that the foreseen future operational model horizontal resolution is planned to around 4-5 km (i.e. the scale where the NH effects starts to be theoretically visible) it is desirable to allocate the traditional NH workforce to the area of NH dynamics and its interaction to the other model components.

OBJECTIVES AND BENEFITS

The planned action should lead to two main outcomes: First to master the NH dynamics in standard way for operational code in terms of code experience and chance to detect and evaluate limitations. Moreover as they are presently some open issues related to the NH code, it is also desirable to arrive to some common agreement beneficial or at least acceptable for all potential code users with their different area and resolution focuses (Aladin, Arome, ECMWF, Hirlam).

The second objective for the planned project should be to reach a state where the NH dynamics offers viable alternative for the operational implementation in terms of forecast quality, stability and computational cost.

The expected benefits are:

1. Faster and targeted NH research: Up to now the final target for any NH development was limited to just better NH dynamics. This should be generalized now to aim also the improvement of the forecast skills of the whole NH model.
2. Systematically maintain experience of the NH dynamics (beneficial also to the partners).
3. Improvement of the operational model (or at least possibility to profit in the future if there is no real benefit from switching to NH dynamics for the planned resolution 4-5 km).

ORGANIZATION

The planned project will be organized into following tasks:

1. WP1: Validation of the current NH dynamics.
2. WP2: Additional development or validation
3. WP3: Comparison of the NH and hydrostatic dynamics
4. WP4: Code optimization of the NH dynamics (optional)
5. WP5: Operational implementation

WP1 Validation of the current NH dynamics

This step is essential for the starting point definition for the subsequent tasks. The current NH code significantly evolved since the last LACE NH development. Most of the changes came with the promotion of the limited area model (LAM) version to the global model geometry. Logically an extended validation of the new code for LAM is desirable. Additionally the worse stability of the ICI scheme (iterative scheme, for one iteration known as predictor/corrector) with physics with respect to simple time step with no iteration looks suspicious.

Task 1.1 - **Redo academic tests with the recent version of the NH dynamics**

Contributors: J. Mašek (Sk) and J. Vivoda (Sk)
Resources: run localy at SHMU
Means: 1 month
Schedule: first half of 2008

Task 1.2 - **Check the way the physics is coupled to dynamics in ICI scheme**

Contributors: I. Bašták Ďurán (Sk), P. Smolíková (Cz), F. Váňa (Cz)
Resources: none (just code work)
Means: 0.5 month
Schedule: first half of 2008

WP2 Additional development and validation

There are various subjects which needs to be still developed or at least carefuly validated. Some of them are critical for the successful operational implementation (like LBC treatment), the others can just extend the NH dynamics skills being closer to hydrostatic model (VFE) or simply using the new possibilities offered by fully elastic NH core (fully elastic coupling of physics to dynamics, phys tendency to w).

Task 2.1 - **Time step organization - improved coupling of physics to dynamics**

Description: The aim is to improve stability of the existing code within the ICI. Aditionaly it is desirable to reach higher accuracy (idealy of 2nd order).
Contributors: I. Bašták Ďurán (Sk) and belgic team
Resources: stay at RMI (Belgium) for flat rate funds
Means: 1 month
Schedule: second half of 2008

Task 2.2 - **Vertical finite element discretization for NH dynamics**

Description: Continuation of the ongoing research
Contributors: J. Vivoda (Sk)
Resources: local work at SHMI + 2 months of LACE stay
Means: 3 months (2008) + 4 months (2009)
Schedule: continuous

Task 2.3 - **Consistent coupling of physics to fully elastic dynamics**

Contributors: P. Smolíková (Cz)
Resources: local work at CHMI
Means: 0.5 month
Schedule: first half of 2008

Task 2.4 - **Balanced LBC treatment for NH dynamics**

Description: From the practical experience it has been found that the LBCs for NH dynamics requires to be in certain balance. In case the nested model uses different vertical level distribution from the leading model an additional procedure has to be applied to the LBC fields to maintain this balance. The aim of this task should be to define and introduce this technique into Aladin.
Contributors: person applying for the offered stay
Resources: 1.5 month LACE stay at CHMI
Means: 1.5 month
Schedule: first half of 2009

Task 2.5 - **Optimal cycling strategy**

Description: In phase to Task 2.4 and the used data assimilation strategy an optimal way of cycling for the prognostic model fields (including the two additional NH fields) should be defined.
Contributors: person applying for the offered stay

Resources: 1 month LACE stay at CHMI
Means: 1 month
Schedule: second half of 2009

Task 2.6 - **Introducing physical tendency to w**

Description: Having the prognostic equation for w (vertical component of the flow field) it can be further completed by diabatic tendency of this field computed by the physics.
Contributors: I. Bašták Ďurán (Sk), F. Váňa (Cz), P. Smolíková (Cz)
Resources: 1 month LACE stay at CHMI plus local work
Means: 2 months
Schedule: first half of 2009

Task 2.7 - **Dealing with problems detected during parallel test with hydrostatic dynamics**

Description: This task is sort of reserve to be able to deal with any unexpected detected during parallel execution of hydrostatic and NH full models.
Contributors: R. Brožková (Cz), J. Mašek (Sk), P. Smolíková (Cz), J. Vivoda (Sk), F. Váňa (Cz),...
Resources: preferably local work with reserved 1 month LACE stay
Schedule: continuous during 2009

WP3 Comparison of the NH and hydrostatic dynamics

The two full models differing by just used dynamics should be compared by a parallel execution being the standard way used for introduction of the new model version to the operational. This comparison should be ideally done for the resolution targeted for the operational execution. (Indeed it can be tested for other resolutions as well.) As such resolution is foreseen to around 4-5 km of horizontal mesh, this task should succeed successful implementation of hydrostatic model to the same resolution.

Task 3.1 - **Implementation of (hydrostatic) operational model to the targeted resolution**

Description: From the academic simulation it becomes clear that to use NH dynamics becomes indispensable for resolutions bellow 1 km. Indeed it is always safer to use more general NH approach, but from practical experience it brings nearly no profit for resolutions coarser than 10-20 km. Logically to really profit from the NH dynamics, one needs sufficient model resolution (the higher the better). Aiming the available computing resources in LACE by end of 2009, it is realistic to consider LACE domain with resolution of 4-5 km and around 50-60 vertical levels. The necessary prerequisite to operational implementation of the NH dynamics should be then to successfully implement operational model (based on hydrostatic assumption) to such resolution. Alternatively, if the VFE scheme is ready for NH dynamics, the hydrostatic reference should contain also this vertical discretization technique.
Contributors: CHMI team

Resources: local work at CHMI
Means: 2 months
Schedule: first half of 2009

Task 3.2 - **Extensive comparison of the hydrostatic and NH model results**
Description: The Aladin dynamics offers unique possibility for direct comparison of hydrostatic and NH dynamics under equal conditions. The aim of this study is to regard the differences between hydrostatic and NH dynamics in terms the model results quality.
Contributors: R. Brožková (Cz)
Resources: local work at CHMI
Means: 2 months
Schedule: first half of 2009

WP4 Code optimization of the NH dynamics

Once the NH dynamics offers stable and accurate performance competitive to the hydrostatic dynamics, the code should be inspected from the computation efficiency and portability point of view. Indeed the more complex NH dynamics means some extra cost to the model. It is however important that this additional increase remains proportional to a cost adequate for addition to two more prognostic variables. It is also extremely important that the NH model keeps the same qualities for the different computing platforms like vectorisation, support to for both MPI and OpenMP parallelization (in terms of performance and neutrality to results to number of used CPU),…

Task 4.1 - **Optimization of the NH code**
Contributors: F. Váňa (Cz), ASC
Resources: local work at CHMI
Means: on demand
Schedule: second half of 2009

Task 4.2 - **Ensuring the portability of the code**
Contributors: ASC
Resources: local work
Means: optional on demand
Schedule: second half of 2009

WP5 Operational implementation

Once the NH version is capable to offer better results of an affordable cost for the targeted model resolution it can be switch to the operational. Alternatively a clear guidance has to be given for the validity of the hydrostatic approximation and from which scales the use of NH dynamics starts to be indispensable.

Task 5.1 - **Switch operational model at CHMI to NH dynamics**
Contributors: R. Brožková (Cz) and operational team of ALADIN/CE
Resources: local work at CHMI
Means: 1 month
Schedule: second half of 2009

Task 5.2 - **Provide guidance for the other centers**
Contributors: R. Brožková (Cz)
Resources: local work at CHMI
Means: 1 month
Schedule: second half of 2009

TIME TABLE

The project is designed for period 2008-2009. This means it should be finished by the end of 2009.

DELIVERABLES

In the bracket the importance of the task with respect to the whole project success is given. The task recognized as critical are essential for the success of the whole project. The successful fulfillment of the optional tasks would indeed further help to the whole project but it is not critical for the whole project success.

Task 1.1 (critical) – summer 2008
Task 1.2 (critical) – summer 2008
Task 2.1 (optional) – first outcome by end of 2008, possibly further continuation
Task 2.2 (optional) – end of 2009 (if any)
Task 2.3 (optional) – summer 2008
Task 2.4 (critical) – summer 2009
Task 2.5 (critical) – end of 2009
Task 2.6 (optional) – summer 2009
Task 2.7 (critical) – end of 2009
Task 3.1 (critical) – summer 2009
Task 3.2 (critical) – autumn 2009
Task 4.1 (critical) – end of 2009
Task 4.2 (optional) – end of 2009
Task 5.1 (optional) – end of 2009
Task 5.2 (critical) – end of 2009

LINKS TO OTHER PROJECTS

The task 3.1 (essential for this project) requires success of the project “Operational ALARO configuration at scales around 5km mesh-size”. Additionally it is also desirable to harmonize the NH development with the other partners contributing to the NH code development (Météo-France, Hirlam), especially to the ongoing activity of Météo-France and ECMWF on the developing NH dynamics for the spherical geometry.

RESOURCES OVERVIEW

In the following list the estimated length (in months) of work is given for the involved institutes. The tasks remaining unknown are listed in bracket (as the task number) at the appropriate place.

Local work at CHMI	**7.5**+(2.7)+(4.1)
Local work at SHMU:	**6**
Local work of ASC	(4.1)+(4.2)
LACE stays at Prague	**4.5**
LACE stays at other centers	**2**
Others (outside LACE)	
IRM (Belgium)	**1**
TOTAL	**21** +(2.7)+(4.1)+(4.2)

Here is already considered 1 month on LACE funds (stay at CHMI) as the reserve for task 2.7

COMMITMENTS OVERVIEW

Following table lists the LACE means (in months) related to the research and development for the project. The means of people outside the LACE or the project coordination effort is not included there.

I. Bašták Ďurán(Sk)	2.5	
R. Brožková(Cz)	3.5	+2.7
J. Mašek(Sk)	0.5	+2.7
P. Smolíková(Cz)	1.0	+2.7
F. Váňa(Cz)	0.5	+2.7+4.1
J. Vivoda(Sk)	7.5	+2.7
ASC		+4.1+4.2
offered stays	2.5	
CHMI operational team	2.5	
TOTAL	20.5	+(2.7)+(4.1)+(4.2)

Here the total number doesn't correspond with the total resources due to the fact that the task 1.2 (0.5 person/month) doesn't require resources.