Working Area Dynamics & Coupling

Work Plan

Prepared by:	Area Leader Petra Smolíková
Period:	2016
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1 Introduction and background

This material is being prepared for LACE Steering Committee which is invited to give opinion on the activities and resources planned here.

2 Goals

Our main goals in the area of Dynamics&Coupling are strongly connected to the future increase in the horizontal and vertical resolutions of model ALADIN/ALARO/AROME applications. We have to face related problems which may in the future include revisiting of the basic choices made during the model design in the past, as for example chosen time and space discretizations. We have been working already for many years on the implementation of finite element method in the vertical discretization of ALADIN NH (Task 1) aiming to increased accuracy in higher resolutions. There are signals from Météo France that with the increase in horizontal resolution the used time scheme (semi-implicit with linear part being solved implicitly and non-linear part being solved through iterated centred implicit method, linearization being done according to a simple horizontally homogeneous basic state constant in time) may not guarantee physically correct and numerically stable solution converging to the right solution when the time step is being decreased. We need to know more about the envisaged problems and start to anticipate solutions (Task 4). Another part which has to be reconsidered is the horizontal diffusion being solved through a combination of spectral diffusion and SLHD scheme. The current solution has an enormous number of tuneable parameters. We feel as an urgent need to prepare a methodology how to tune these parameters for different resolutions (Task 3) or to try to redesign this part of the model to answer better the possible requirements.

We do not have any plans in coupling for the next year.

Task 1. VFE NH

Subject: Design of vertical finite elements scheme for NH version of the model

Description and objectives: The main objective of this task remains the same for years - to have a stable and robust vertical finite elements (VFE) discretization to be used in high resolution real simulations with orography with the expected benefit being the enhanced accuracy for the same vertical resolution when comparing with vertical finite differences (VFD) method. We want to stick as much as possible to the existing choices in the design of dynamical kernel (SI time scheme, mass based vertical coordinate) and to stay close to the design of VFE in hydrostatic model version (according to Untch and Hortal).

In the last year, vertical operators for derivative and integral with specific boundary conditions have been revisited. In the cooperation with our HIRLAM colleagues, invertible operators needed for transformation of prognostic variable for vertical velocity and vertical divergence have been defined and prepared to be implemented in the code. The goal of all these changes is a simple and physically correct discretization of Euler's equations. After all

changes being finished, new testing is anticipated for the next year in 2D vertical slice model and in real simulations in high resolution (around 1km). The important part of the task would be the publication of results in a reviewed journal.

Proposed contributors: Jozef Vivoda (Sk), Petra Smolíková (Cz)

Estimated efforts: 2 months (stay at CHMI, Prague), 4 months of local work

Planned deliverables: results of tests, a paper prepared for publication in a reviewed journal

Task 2. SL scheme

Subject: 2.1 Application of ENO technique to semi-Lagrangian interpolations

Description and objectives: High order semi-Lagrangian interpolations, in 1D typically represented by cubic Lagrange polynomial on 4-point stencil, are not monotonic and produce spurious overshoots in the vicinity of discontinuities or sharp gradients. Their quasi monotonic version exists, but simple cut off procedure reduces accuracy dramatically. However, after interpolation stencil was extended to 6-points, 3rd order ENO (Essentially Non-Oscillatory) interpolation was implemented in the code of the model (CY40). It is able to reduce spurious oscillations/overshoots while keeping high order of accuracy uniformly. The aim of the work is to evaluate its performance/cost. First experiments have been already done in 2D vertical plane model. The already proposed solution could be extended to WENO (Weighted ENO) technique, in which three interpolators are combined depending on the advected field.

Proposed contributors: Alexandra Craciun (Ro), supervision of Ján Mašek (Cz)

Estimated efforts: 1 month (stay at CHMI, Prague), 1 month (local work, CHMI)

Planned deliverables: tests results, conclusions in a report

Subject: 2.2 COMAD weights for SL interpolations

Postponed from 2015.

Description and objectives: The COMAD weights have been designed at ECMWF (Sylvie Malardel). The linear and cubic semi-Lagrangian weights are modified to take into account the deformation of air parcels along each direction, with deformation factor defined with the respect to the local velocity in the given direction and the timestep used. The proposed modification had a positive impact on the objective scores of the IFS runs and on the AROME 1.3km runs. We would like to know if we may get some benefit from this modification for the local model ALARO.

Proposed contributors: Petra Smolíková (Cz)

Estimated efforts: 1 month (local work, CHMI)

Planned deliverables: testing results

Task 3. Horizontal diffusion

Subject: 3.1 Tuning and redesign of the horizontal diffusion depending on the scale

Description and objectives: A numerical diffusion has a significant role among the other mixing parameterizations since it must be present from planetary to viscous scales, mimicking the continuation of the energy cascade at the end of model spectrum and simulating residual processes which are not well captured by other parameterizations, as well as acting to filter-out unwanted discretization noise. The SLHD (semi-Lagrangian horizontal diffusion) is a flexible tool to represent the numerical diffusion in the model which was proven to be well working throughout a wide range of resolutions. Nevertheless, this tool has an enormous number of tunable parameters and includes not only flow dependent grid-point diffusion, but a supporting spectral diffusion as well. The behavior of the whole scheme in high resolutions appears to be not understood well. The topic covers the proposal of an experimental setup enabling to test schemes in multiscale environment, developing tools to diagnose energy and entropy in the model system and SLHD tuning to get a consistent and scale invariant parameterization of mixing processes. For the start of the work, the diffusion coefficient used in SLHD and being a monotonic function of the total flow deformation along the terrain-following vertical levels will be redesigned.

Proposed contributors: Viktória Homonnai (Hu), Petra Smolíková (Cz)

Estimated efforts: 2 months (1 month – research stay in Prague, 1 month of local work)

Planned deliverables: problem analysis, eventually redesign of SLHD; testing, report

Task 4. Evaluation of the model dynamical core in very high resolutions

Subject: 4.1 Clear comparison of SETTLS and ICI time schemes

Postponed from 2015.

Description and objectives: On workshops, during meetings with our colleagues from ALADIN, HIRLAM and ECMWF, in email exchanges, we are facing the complaints on the speed, affordable timestep, computational time requirements and stability properties of the centred iterative time schemes (called PC scheme) developed under the RC LACE auspices. In 2011, a study of Filip Váňa has shown problems which may be faced when using alternative non-iterative 2-time-level scheme called SETTLS. From our case studies we believe that iterative schemes offer better stability properties that SETTLS without danger of creating spurious oscillations. We would like to compare the two alternative kinds of time schemes available in the code of ALADIN/ALARO/AROME model and show benefits and drawbacks of them in a clear and convincing way.

Proposed contributors: Petra Smolíková (Cz), Jozef Vivoda (Sk)

Estimated efforts: 2 months of local work

Planned deliverables: draft of paper

Subject: 4.2 Upper boundary conditions

Postponed from 2015.

Description and objectives: Mariano Hortal (HIRLAM, Spain) has introduced upper boundary nesting based on Davies relaxation similar as it is used on lateral boundaries. He has shown that this relaxation helps to get rid of upper level explosions observed in real cases for SETTLS time scheme. We would like to understand better the behaviour on the upper boundary and its interaction with PC time scheme used in most operational applications.

Proposed contributors: Petra Smolíková (Cz)

Estimated efforts: 1 month of local work

Planned deliverables: phasing of the upper boundary relaxation implemented by Mariano Hortal to CY38t1 + redesign if needed, testing, conclusions in a report

3 Summary of resources

The total effort invested into the area of Dynamics&Coupling in frame of LACE during 2016 is expected in the amount of 14 person/months, 4 person/months from that supported by LACE budget directly. The expected resources are comparable to those invested in the area in 2015.

Task		Subject	Resources	
			Total	Stays
1. VFE NH	1.1	Design of VFE in NH model	6	2
2.SL scheme	2.1	Application of ENO technique in SL interpolations	2	1
	2.2	COMAD weights for SL interpolations	1	0
3.Horizontal diffusion	3.1	Tuning and redesign of the horizontal diffusion depending on the scale	2	1
4.Evaluation of the dynamical core in very high resolutions	4.1	Clear comparison of SETTLS and ICI time schemes	2	0
	4.2	Upper boundary conditions	1	0
Total manpower			**14**	**4**

4 LACE supported stays

1) Design of VFE in NH model – Jozef Vivoda (Sk), 2 months in Prague
2) Application of ENO technique to SL interpolations – Alexandra Craciun (Ro), 1 month in Prague
3) Ideal share between horizontal turbulence and numerical diffusion – Viktoria Hommonai (Hu), 1 month in Prague

5 Meetings and events

1) 26th ALADIN Workshop & HIRLAM All Staff Meeting 2016 -- participation of Petra Smolíková
2) EWGLAM & SRNWP joint meetings - participation of Petra Smolíková
3) LACE/HIRLAM Dynamics Working Days – 2 weeks in June 2016, Prague, expected participants: Alvaro Subias (HIRLAM), Juan Simarro (HIRLAM), Jozef Vivoda, Petra Smolíková
   - the event is opened to all interested participants

6 Risks and constrains

As the most urgent we find the task to publish the already obtained results in reviewed journals and we will concentrate on this aim. We keep the expected amount of manpower invested into the Working Area of Dynamics&Coupling in 2016 comparable to previous years. However, we believe that some topics in the area of Dynamics&Coupling, connected to the time scheme design and tuning of horizontal diffusion, may become very urgent as soon as horizontal resolution of our operational applications will exceed 2km. We are happy to find an appropriate candidate to work on one of these topics in Viktória Hommonai from Hungary.