Working Area Dynamics & Coupling

Work Plan

Prepared by:	Area Leader Petra Smolíková
Period:	2015
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1 Introduction and background

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

2 Goals

The core development in the area of Dynamics&Coupling in the frame of RC LACE is concentrated at CHMI, Prague, with essential input from our Slovak colleagues. Our long-term goal is to have more people working in this area also in other centres and from young scientists from Hungary and Romania. We feel our lack of resources invested in publication of results achieved and we would like to concentrate on this goal in 2015. Our main goals in the area are strongly connected to the expected increase in the horizontal and vertical resolutions of model ALADIN/ALARO/AROME applications, operational and experimental.

3 Main R&D activities

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). More specific plans for 2015 are the following:

- thorough testing of the VFE implementation in the cycle CY40T1 in very high resolutions (<1km) with the emphasis on stability and accuracy properties; this task comes after results of experiments being done at Météo France (Karim Yessad) with AROME 1.3km where the stability of VFE scheme was significantly worse than stability of FD scheme; this is not the case for lower resolutions (2.2km); we would like to understand reasons for this behavior and to run experiments in high (1km) resolution with ALARO model
- to understand the saturation of accuracy for high spline orders and high vertical resolutions observed for designed FE vertical operators

- to continue the study of possible formulations of vertical operators for integral and derivation which are inverse of each other; to find a formulation which will work well with the whole scheme and could be used in the transformations of vertical velocity *w* to vertical divergence *d* and vice versa to eliminate the up to now used finite difference method – a collaboration with our HIRLAM colleagues is foreseen on this subject

- to eliminate further remaining finite difference features of the current vertical discretization; particularly the top and bottom boundary conditions of the vertical Laplacian operator

- to show the benefits of the proposed method in comparison with the finite difference method used in vertical discretization (either on enhanced theoretical accuracy of vertical operators used, or if possible on comparison of analytical and numerical normal modes of linear Euler equations over non-flat orography)

- **to write a paper for a scientific review**

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

Estimated efforts: 1 month (stay at CHMI, Prague), 4 month of local work

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

In the following task we will continue in the already started work and keep track of work done at ECMWF.

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, if interpolation stencil was extended to 6-points, 3rd order ENO (Essentially Non-Oscillatory) interpolation could be applied. It is able to reduce spurious oscillations/ overshoots while keeping high order of accuracy uniformly. Aim of the work is to implement ENO interpolation technique in ALADIN and evaluate its performance/cost. A first study of the problem has been already done in 1D – linear advection toy model, and for quadratic interpolators in full model code and 2D vertical plane model. Quadratic interpolators have been found too smoothing, but 1D experiments show promising results for cubic

interpolator, or WENO technique, in which two interpolators are combined depending on the advected field. We will continue in the already started work.

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

Estimated efforts: 1 month (stay at CHMI, Prague), 0.5 month (local work, CHMI)

Planned deliverables: problem analysis, code modification, testing

Subject: 2.2 COMAD weights for SL interpolations

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: 0.5 month (local work, CHMI)

Planned deliverables: testing

Task 3. Physics-dynamics interface

A wider platform of problems is hidden under the name of “Physics-dynamics interface”. Some topics in this group were postponed from the previous year and some of them have been already started at the end of 2013.

Subject: 3.1 Feasibility study to add the physical tendency of vertical velocity to the adequate prognostic (NH) variable

Description and objectives: For parameterization schemes used in HPE systems, the horizontal momentum 'feels' the sub-grid effects of mountain drag, turbulence and convection. The impact of these processes on the vertical momentum in the case of NH dynamics has to be reconsidered. The first of the three processes being of little importance, just two others will be studied. For the turbulence parameterization, the same down-gradient approach as for horizontal momentum can be applied to vertical momentum with an additional attention paid on the vertical staggering. For the third process, the fact that vertical sub-grid convection transports upwards a systematically rising vertical velocity ought to have some direct impact on the model's dynamics via the 3D divergence term, on top of the already considered thermodynamic impact of deep convection in non-hydrostatic conditions. First implementation of turbulent component to the prognostic variable for

vertical motion has been prepared and tested in 2013 and 2014 with the conclusion that there is an important impact observed. We need to continue in the already started work.

Proposed contributors: David Lancz (Hu), Petra Smolíková (Cz)

Estimated efforts: 1 month (stay at CHMI, Prague), 0.5 month (local work, CHMI)

Planned deliverables: Report from stay.

Subject: 3.2 Design of the ideal share between the horizontal turbulence and numerical 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 is a flexible tool to represent the numerical diffusion in the model. On the other side there is the horizontal extension of the scheme for vertical diffusion called TOUCANS as a tool for the horizontal turbulence control. 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.

Proposed contributors: Radmila Brožková , Ján Mašek, Petra Smolíková (Cz)

Estimated efforts: 2.5 months (local work, CHMI)

Planned deliverables: analyse the problem, propose tools to diagnose energy in the system

Task 4. 1D2D turbulence scheme for ALARO

When applying simple scale analysis to turbulent processes it is evident that for kilometric scales the horizontal and vertical components might be of comparable effects. It follows that horizontal components can't be neglected. In the design of the new turbulence scheme they are treated as the 2D horizontal extension of the 1D scheme for vertical diffusion called TOUCANS. The whole design of this complex system is a task lying on the border of dynamics and physics, dynamics being touched particularly if horizontal diffusion is considerated, and by the use of SLHD data flow. The work has to be phased with actions of Working Group on Physics on the same subject.

Subject: 4.1 Scientific validation

Description and objectives: Scientifically correct behaviour of the whole 1D2D system is a necessary condition needed to be satisfied to be able to fulfil further tasks. The vertical part

has been prepared in the scheme TOUCANS, while the horizontal part has to be redesigned and modified to get consistent system on the latest model cycle. It follows that the compliance of the whole 1D2D turbulence scheme behaviour with the laws for transport of energy from bigger to smaller scales has to be carefully examined. Energy spectrum study is foreseen as an instrument for such validation. Preparation of a testing environment is considered as a part of the issue.

Proposed contributors: Ivan Bašťák-Durán (Cz)

Estimated efforts: 0.5 month (stay at HMZS, Ljubljana)

Planned deliverable: code modification to get working 1D2D system for turbulence, report on the results achieved

Subject: 4.2 Tests in <1 km resolutions

Description and objectives: As soon as the previous task is successfully finished, academic tests with the full model may be targeted to further study scheme behaviour and its interconnection with other model parts. Very fine horizontal resolutions (subkilometric) are needed for such tests.

Proposed contributors: Ivan Bašťák-Durán (Cz)

Estimated efforts: 0.5 month (stay at HMZS, Ljubljana), depends on the progress achieved

Planned deliverable: ???, report

Task 5. Evaluation of the model dynamical core in very high resolutions

Subject: 5.1 Clear comparison of SETTLS and ICI time schemes

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: 1 month of local work

Planned deliverables : draft of paper

Subject: 5.1 Upper boundary conditions

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 : analysis of the problem, proposed solution for upper boundary when PC scheme is used

Task 6. LBC coupling strategy

Subject: 6.1. Rapid changes in surface pressure field

Description and objectives: Interpolation in time applied on LBC data of the large scale model to get the data on lateral boundaries for each timestep of a LAM distorts the model fields and can lead to LAM forecast failures in case of fast propagating storms. The analysis of the MCUF (Monitoring the Coupling-Update Frequency) field from ARPEGE coupling files for the common LACE coupling domain may help to monitor the occurrence of such storms to draw conclusions on coupling zone positioning etc. Distinct warning index could be designed to capture high precipitation events again with consequences on LACE domain boundaries. It is a continuation of work from 2013.

Proposed contributors: Martina Tudor (Cr)

Estimated efforts: 1 month (local work, DHMZ)

Planned deliverable: ???, report

4 Summary of resources

The total effort invested into the area of Dynamics&Coupling in frame of LACE during 2015 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 2014.

Task		Subject	Resources	
			Total	Stays
VFE NH	1.1	Design of VFE in NH model	4	1
SL scheme	2.1	Application of ENO technique in SL interpolations	1.5	1
	2.2	COMAD weights for SL interpolations	0.5	0
Phys-dyn interface	3.1	Physical tendency of w	1.5	1
	3.2	Ideal share between horizontal turbulence and numerical diffusion	2.5	0
1D2D turbulence	4.1	Scientifique validation	0.5	0.5
	4.2	Testing	0.5	0.5
Evaluation of the dynamical core in very high resolutions	5.1	Clear comparison of SETTLS and ICI time schemes	1	0
	5.2	Upper boundary conditions	1	0
Coupling strategy	4.1	Rapid changes in surface pressure field	1	0
Total manpower			**14**	**4**

5 LACE supported stays in 2015

1) VFE – Jozef Vivoda (Sk), 1 months in Prague
2) ENO technique to SL interpolations – Alexandra Craciun (Ro), 1 month in Prague
3) Physical tendency of vertical velocity – David Lancz (Hu), 1 month in Prague
4) 1D2D turbulence in ALARO - Ivan Bašťák-Durán (Cz), 1 month in Ljubljana

6 Meetings and events

1) 25st ALADIN Workshop and & HIRLAM All Staff Meeting 2015, 13-16 April 2015, Copenhagen, Denmark (participation of Petra Smolíková).
2) 37th EWGLAM & 22th SRNWP joint meetings (participation of Petra Smolíková).

7 Risks and constrains

It has to be pointed out again that the success of our endeavour is highly dependent from the ability to draw appropriate researchers into the area. We keep the expected amount of manpower invested into the Working Area of Dynamics&Coupling in 2015 comparable to previous year.