Working Area Dynamics & Coupling

Work Plan

Prepared by:	Area Leader Petra Smolíková
Period:	2014
Date:	10/09/2013

1 Introduction and background

Let us mention at the beginning that we see great benefit of longer period planning. In one year period (updated twice per year) we have to repeat that the same topics are being solved and we have to repeat frequently that due to still unavailable workforce, the work on some of the topics has to be postponed to the next reporting and planning period. On the other hand, in the area of Dynamics&Coupling there are rather quickly developing topics as well (NH VFE) and it is worth to describe the progress achieved and the short term plans in these topics.

2 Goals

We should say that the RC LACE goals in the area of Dynamics&Coupling are rather longer term and hence have not changed since the last plan prepared for 2013. Let us repeat them in short.

Our aim is to prepare the dynamical kernel of model ALADIN for operational use in 1-2km horizontal resolutions and even subkilometric horizontal resolutions. Vertical resolutions are expected to be increased proportionally. Knowing that in these scales the NH dynamics plays no more a negligible role, we have to test the NH dynamical kernel of model ALADIN with the emphasis on stability properties comparable to hydrostatic dynamics, satisfactory accuracy and robustness. The price to be paid for that may be reduced effectiveness and increased demands on computational time and memory. We have to keep these requirements in reasonable bounds.

For NH dynamical kernel, several methods were developed in the past to reach satisfactory stability properties for reasonable timesteps used. Hence, the NH dynamics requires the usage of predictor-corrector time scheme and two distinct prognostic variables for vertical motion, the vertical divergence based one in the implicit (linear) part and vertical velocity in the non-linear part, with the need of transformations between them. The SI reference temperature used has to differ in terms involving the vertical propagation of elastic waves and the rest when 2TL scheme is applied with the consequence of satisfactory robustness of the implicit treatments.

To enhance accuracy of proposed solutions or to overcome potential problems, there are scientific issues to be addressed when approaching to hexametric scales. First of all, potentially more accurate vertical discretisation based on finite elements method (VFE) has been investigated, scientifically designed and implemented in last years. At the end of 2012 we succeeded to achieve stability in very tough tests in the vertical slice (2D) model as non-linear non-hydrostatic flow over Agnesi shaped mountain and the so called Straka test simulating a cold bubble of potential temperature. In 2013 we started academic tests in

three dimensions in the adiabatic conditions over steep orography and real case simulations with the first version of model ALARO (2.2km). All results are promising, not indicating particular stability or robustness problems. The enhanced accuracy not being detected yet, more tests and studies of designed vertical operators have to be prepared in 2014 with the connection to the degree of B-splines used as basis for finite element discretization. There are other important issues linked to this topic.

Interactions of model dynamics with the other model components within the full complex operational system have to be studied (accuracy and design of the physics-dynamics interface, mutual influence with physical parameterizations as vertical turbulence) as well as the strategy of lateral coupling of the finer resolution LAM to the leading model (aspects of the coupling update frequency).

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 is 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 are the following:

- to phase the existing working VFE implementation into the official IFS/ARPEGE/ ALADIN cycle cy40t1; this requires non negligible modifications in the current VFE NH code version being prepared on cy36t1; a cooperation with Météo France is expected on this task (Karim Yessad)

- to adapt the current implementation to the global model ARPEGE/IFS; to check if the current solution is compatible with the option LSIDG (horizontally varying mapping factor in the reference state for the linear model); a cooperation with Météo France, Hirlam and possibly ECMWF

- thorough testing of the VFE implementation in the cycle cy40t1 with the emphasis on stability and accuracy properties, on the convergence of the SI solver and its speed; we need to understand clearly what is the reason for satisfactory behavior of the VFE scheme in comparison with the previous attempts

- to study the influence of the B-spline order on the accuracy and the time stepping stability of the whole system; so far all tests were restricted to the cubic B-splines only, but the implementation is general concerning the degree of splines

Some of the goals may be accomplished during autumn 2013, but it is difficult to prepare plans on month basis.

Proposed contributors: Jozef Vivoda (Sk), Petra Smolíková (Cz), Alvaro Subias (Hirlam Es)

Estimated efforts: 6 months

Planned deliverables: code modification phased to the cycle cy40t1 (official issue at the beginning of 2014); thorough tests of this modification with the emphasis on stability, accuracy and convergence of the SI solver; reports from stay; paper prepared for publication in a reviewed journal

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Tasks 2 and 3 are partly adopted from the RC LACE plan for the area of Dynamics&Coupling for 2013. Not being touched at all in 2013 due to no availability of the needed workforce but being felt as important and unavoidable.

Task 2. 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 we expect to start the respective work in 2013.

Subject: 2.1 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.

Proposed contributors: David Lancz (Hu)

Estimated efforts: 1 month

Planned deliverables: depend on the development of the topic during autumn 2013

Subject: 2.2 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.

Proposed contributors: ???, supervision of Ján Mašek (Cz)

Estimated efforts: 1.5 month (local work)

Planned deliverables: problem analysis, code modification, testing

Subject: 2.3 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 (Cz)

Estimated efforts: 2.5 months (local work, CHMI)

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

Task 3. 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: 3.1 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. 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: Ján Mašek (Cz)

Estimated efforts: 1 month (local work, CHMI)

Planned deliverable: report

Subject: 3.2 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: Ján Mašek (Cz)

Estimated efforts: ???, depend on the progress achieved

Planned deliverable: ???, report

Task 4. LBC coupling strategy

Subject: 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 2012.

Proposed contributors: Martina Tudor (Cr)

Estimated efforts: 2 months (local work, DHMZ - Zagreb)

Planned deliverable: ???, report

4 Summary of resources

The total effort investigated to the area of Dynamics&Coupling in frame of LACE during 2014 is expected in the amount of 16 person/months, 4 person/months from that supported by LACE budget directly.

Subject	Manpower	LACE	Other (Hirlam)
VFE NH	6	5	3
Phys-dyn interface	5	5	1
1D2D turbulence scheme	1	1	0
Coupling strategy	2	2	0
Total:	**14**	**13**	**1**

5 Meetings and events

1) 24st ALADIN Workshop and & HIRLAM All Staff Meeting 2014, 7-11 April 2014, Romania (participation of Petra Smolíková).

2) 36th EWGLAM & 21th SRNWP joined meetings, 29 September - 2 October Offenbach Germany (participation of Petra Smolíková).

LACE supported stays in 2014

1) VFE – 3 months in Prague (CHMI)

2) Physics-dynamics interface – 1 month in Prague (CHMI)

6 Risk and constrain

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 decrease the expected amount of manpower invested into the Working Area of Dynamics&Coupling in 2014 compared to previous years. The reason is that we want to stick to the real capacities we have and try to plan the amount of work which could be possibly accomplished with the available workforce. There are further topics which could be solved in case of extra manpower.