Working Area Dynamics & Coupling

Work Plan

Prepared by:	Area Leader Petra Smolíková
Period:	2013
Date:	01/03/2013

1 Introduction and background

Considering the rather longer term character of the solved problems in the Area of Dynamics&Coupling, we stick on the strategy to continue the already started work (VFE NH), and to start the foreseen work in topics postponed from 2012 for the reason of non-availability of the needed workforce (physics-dynamics interface). On the border of physics and dynamics we expect to tackle the problem of 3D turbulence scheme in close cooperation with the LACE working group on physics. On top of these three main courses of research and development, we face the needs of coupling to the leading model in high resolutions.

2 Goals

We follow up on the previous project "Toward an operational implementation of the NH dynamics" being solved in 2008-2010. This project confirmed that the NH dynamics is ready for operational use for the models with resolution between 4-5 km and more than 60 vertical levels. Moreover, NH dynamics can be activated at any time through namelist modifications and eventually by extension of initial file by two NH prognostic variables. On the other hand, it was concluded that NH dynamics brings no extra benefit for considered model resolutions, except for strong precipitations over mountainous regions where it slightly reduces model error. The pragmatic suggestion for those scales then was to remain hydrostatic and invest the spared cost elsewhere (better vertical discretization, more demanding physical parameterizations etc.). Applications with horizontal resolutions around 4 km became operational in several centres afterwards.

Very similar approach has to be adopted for finer resolutions now to be prepared for operational use of models in 1-2km horizontal resolutions and even subkilometric horizontal resolutions. The conclusions of previous project have to be revisited for these finer scales.

On top of that, there are scientific issues to be addressed when approaching to hexametric scales to enhance accuracy of proposed solutions or to overcome potential problems. Thus more accurate vertical discretisation (VFE) being scientifically designed and implemented for already several years is felt to become an urgent topic. The work on this topic has been significantly moved forward in the last year when 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. For the next year we plan to start 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).

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: According to "The LACE scientific strategy for years 2012-2019" from March 2012 and in terms of the document "The work plan on High-Performance Computing for HIRLAM/ALADIN models" elaborated by the HIRLAM/ALADIN dynamics/physics expert group in May 2011, an implementation, testing and validation of the Euler Equations system (NH) cast with vertical finite elements (VFE) discretization is stated as a main scientific goal on the longer term perspective. Despite of being explored for some years already with a minimal manpower dedicated to it big progress has been achieved in this topic, mainly within the frame of LACE. Further endeavour is expected to be spent on this subject in next years. The main objective of this task is to have a stable and robust vertical finite elements discretization to be used in high resolution real simulations with orography with the expected benefit of VFE NH being the enhanced accuracy for the same vertical resolution when comparing with VFD (vertical finite differences) method. The scientific uncertainty of this task is very high since an original never implemented method has to be designed with extreme high number of degrees of freedom and eligible parameters.

A scheme compatible with wide range of vertical level distributions has been developed recently which seem to show satisfactory stability properties in tests with 2D model. Further tests and studies are needed to show that this scheme allows not only stable but accurate enough solution. The VFE implementation has to been reviewed throughout the model code, cleaned and documented. Academic 3D experiments in adiabatic conditions with very steep orography and real case studies with ALARO in 2.2km are foreseen.

Proposed contributors: Jozef Vivoda (Sk), Petra Smolíková (Cz), Juan Simarro (Hirlam Es)

Estimated efforts: 6 months (3 months of local work, CHMI, 2.5 months- LACE supported stay of JV at CHMI, 0.5 month – LACE supported stay of JS at CHMI)

Planned deliverables: scientific report, revisited code modifications, 3D academic experiments results, real case study in 2.2km horizontal resolution

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: 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 (LACE supported stay in Prague)

Planned deliverables: problem analysis, solutions proposal, code modification

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Subject: 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: Ján Mašek (Cz)

Estimated efforts: 1 month (local work, CHMI)

Planned deliverables: problem analysis, code modification, testing

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Subject: 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

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Subject: Impact of horizontal diffusion (SLHD) in AROME with 3DVAR

Description and objectives: Retuning of SLHD parameters for AROME is foreseen after being able to run operationally a data assimilation cycle (3DVAR+OI_MAIN) which is presently in parallel test. The reason for this planned retuning is that SLHD was found useful in AROME for improving precipitation (reducing/eliminating small precipitation spots coming from spurious convection). However, according to the experience 3DVAR has a quit large impact on precipitation (during summer on convection) so it is expected that some more tuning can help on SLHD once running an operational 3DVAR.

Proposed contributors: Balász Szintai (Hu)

Estimated efforts: 1 months (local work, OMSZ)

Planned deliverables: retune SLHD, compare with the old setting

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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: 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: 2 month (local work, CHMI)

Planned deliverable: report

Subject: 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: 0.5 month

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, recommendation on the coupling zone positioning

4 Summary of resources

The total effort investigated to the area of Dynamics&Coupling in frame of LACE during 2013 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	5.5	0.5
Phys-dyn interface	5.5	5.5	0
1D2D turbulence scheme	2.5	2.5	0
Coupling strategy	2	2	0
Total:	**16**	**15.5**	**0.5**

5 Meetings and events

1) 23st ALADIN Workshop and & HIRLAM All Staff Meeting 2013, 15-19 April, 2013, Reykjavik, Iceland (participation of Petra Smolíková).

2) 10th International SRNWP-Workshop on Nonhydrostatic Modelling, 13.-15. May 2013, Offenbach/Main, Germany (participation of Petra Smolíková a Jozef Vivoda).

3) 35th EWGLAM & 20th SRNWP joined meetings, 30 September - 3 October, 2013, Antalya, Turkey (participation of Petra Smolíková).

LACE supported stays in 2013

1) Juan Simarro (Hirlam) – 0.5 month in Prague (CHMI), Autumn 2013

2) Jozef Vivoda (SHMI) – 2.5 months in Prague (CHMI), April, October 2013

3) David Lancz (OMSZ) – 1 month in Prague (CHMI), Autumn 2013

6 Risk and constrain

It has to be pointed out that the success of our endeavour is highly dependent from the ability to draw appropriate researchers into the area.

To be able to share the achieved results between all LACE countries and even with other ALADIN/HIRLAM partners, all colleagues are kindly asked to prepare at least minimum report on their activity, to collect experiments results or summarize in written form their scientific activity. Otherwise, the proper information transmission may not been guaranteed with all the dangerous that follow ☺.