Working Area Dynamics & Coupling

Work Plan

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Period:	2017
Date:	12/09/2016

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

This year the planning for the Area of Dynamics&Coupling was more difficult and the resulting plan is less reliable than in previous years. The reason is that several topics have been closed in the last years ("Application of ENO technique to semi-Lagrangian interpolations", "The physical tendency for vertical velocity in NH") and we plan to start new work. It follows that there is no dedicated workforce for the new topics while some of them could be solved in the cooperation with the HIRLAM consortium which may make the planning even more cumbersome. For this reasons we agreed with our colleagues from Météo France, Belgium and HIRLAM to prepare a meeting at the end of 2016 to discuss the possible tracks we may follow and the promising topics. It may happen that the plans for 2017 will be a subject of more or less extensive changes according to the conclusions from this meeting. The updated plan will be presented to LSC on its spring reunion.

Our main goals in the area of Dynamics&Coupling remain the same as in the last years and are connected to the future increase in the horizontal and vertical resolutions of model ALADIN/ALARO/AROME applications. We have to face connected 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 the increase in 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 (Task 3). 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 2).

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, the phasing of the existing modification of the VFE scheme was planned and we expect it will be finished till the end of 2016, followed by thorough testing in 2D vertical plane and in real simulations. We still have to finish the paper for MWR and keep the code consistent with the work done by our HIRLAM colleagues. Some optimization work is anticipated as well concerning the memory used, vectorization and the amount of tuneable or optional parameters of the designed scheme.

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

Estimated efforts: 2 months – research 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. Horizontal diffusion

Subject: 2.1 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: 1 month – research stay at CHMI, Prague; 1 month of local work

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

The following topics are not precisely defined and even the extent and urgency of their solution is not known. Moreover, the state-of-the-art and current status of research in our partner institutions has to be taken into account. In case LSC is approving the idea to include these topics in the RC LACE plans, some appropriate candidates should be found and dedicated to these topics.

Task 3. Time scheme

Subject: 3.1 Tangent-linear approximated model used in the semi-implicit time scheme of NH dynamics

Description and objectives: The stabilising effect of using the tangent-linear approximated model directly in the semi-implicit time scheme was identified at ECMWF for the hydrostatic IFS by Filip Váňa, and the potential of the new design of SI scheme has been exploited in low spatial resolution (corresponding to usual values in global applications). The most interesting point is the incorporation of orography and real profiles into the linear model, while in the existing reference state for linearization no orography and only constant vertical profiles are present. The consequence of the new design of SI scheme is that there is no need for the spectral space and transformations once the horizontal derivatives are calculated in a local way (for example through finite differences). The crucial point is here the iterative method used to solve the Helmholtz problem and its convergence behaviour in higher spatial resolutions (with steeper slopes).

The aim of this topic would be to extent the hydrostatic tangent-linear model to its non-hydrostatic version for 2D vertical plane model based on the code existing in Météo France, and to try to answer the open questions concerning higher spatial resolutions and designed method properties in idealized 2D vertical plane tests.

Proposed contributors: **NOT KNOWN**

Estimated efforts: 1 month – research stay ????, 1 month of local work

Planned deliverables: code modifications, report

Subject: 3.2 The trajectory search in the iterative time schemes

Description and objectives: It was reported that LPC_FULL scheme with reiteration of SL trajectories produce noisy solution. We have confirmed these results. We tried to understand this fenomenon. As we increase the model horizontal resolution, the local

divergence can increase significantly and the Lipschwitz criteria may be broken locally. Then the trajectory search may become divergent. Then the increase in the number of iterations in the process to search for a SL trajectory may lead to even less accurate solutions. Similar problems have been identified at ECMWF in IFS and fixed by local change of the computation of the half level wind. These considerations should be confirmed in more detailed study.

Proposed contributors: **NOT KNOWN**

Estimated efforts: 2 months of local work

Planned deliverables: report, code changes if needed

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

Subject: 4.1 Upper boundary condition

Description and objectives: There are some indications that upper boundary may cause a problem in higher resolutions. There could be a big jump in vertical levels needed which may destabilize the whole model as it was observed for finite elements used in the vertical discretization of ALADIN-NH.

In general, on the top boundary there is no material surface contrary to the bottom boundary and vertically unbounded atmosphere may be undesirable in some applications. In practice, velocity normal to the upper boundary is set to zero causing wave reflection similar to lateral boundaries. Free-slip conditions are used for other variables. This means that the vertical derivatives of these variables are equal to zero and there is no mass and heat transfer across the boundary. Radiation boundary condition can be imposed by diagnostic relationship between pressure and vertical velocity at the top (Klemp, Durran 1983; Bougeault 1983). However, it is formulated in terms of vertical wavenumbers and frequencies and are difficult to implement. To overcome this problem an explicit absorbing layer is applied for example in SLHD (semi-Lagrangian horizontal diffusion) where spectral diffusion works only when approaching to the top, and an implicit absorbing layer is applied through the coarsening of the vertical resolution when approaching to the top. It should be investigated if there are some new or enhanced problems at the model top in horizontally or vertically higher resolutions and solutions could be proposed if needed.

The work could follow up the work done by Martin Janousek at Toulouse and Prague at the beginning of 21th century :-).

Proposed contributors: **NOT KNOWN**

Estimated efforts: 2 months of local work

Planned deliverables: not defined yet

3 Summary of resources

The total effort invested into the area of Dynamics&Coupling in frame of LACE during 2017 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 previous years. The absolutely necessary condition for fulfilment of our plans is a dedication of the available workforce for the planned topics.

Task		Subject	Resources	
			Total	Stays
1. VFE NH	1.1	Design of VFE in NH model	6	2
2. Horizontal diffusion	2.1	Ideal share between horizontal turbulence and numerical diffusion	2	1
3. Time scheme	3.1	Tangent-linear approximated model used in the semi-implicit time scheme of NH dynamics	2	1
	3.2	The trajectory search in the iterative time schemes	2	0
4. Evaluation of the dynamical core in very high resolutions	4.1	Upper boundary condition	2	0
Total manpower			**14**	**4**

4 LACE supported stays

1) VFE – Jozef Vivoda (Sk), 2 months in Prague
2) Ideal share between horizontal turbulence and numerical diffusion – Viktória Homonnai (Hu), 1 month in Prague
3) Tangent-linear approximated model used in the semi-implicit time scheme of NH dynamics -- ???, 1 month in Prague

5 Meetings and events

1) 27th ALADIN Workshop & HIRLAM All Staff Meeting 2017 -- participation of Petra Smolíková
2) EWGLAM & SRNWP joint meetings - participation of Petra Smolíková

6 Risks and constrains

We start new topics possibly in cooperation with our HIRLAM colleagues. In these topics even the problem formulation and extent may not be exactly known. Moreover, solutions are not known either and problems should be studied extensively to be able to propose some. Hence the predictability of our capacity to finish such topics is low and uncertainty in delivered solutions is high. Anyway, to be able to proceed in problems formulation, investigation and solution, we need to dedicate some workforce to these topics. We are happy that there are appropriate candidates at least for some of them. The concretization of topics, deliverables and workforce dedication will be a subject of further discussion. This plan should be considered as a preliminary one.