Working Area Dynamics & Coupling

Progress Report

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Progress summary

In the working plan for RC LACE area of Dynamics&Coupling for 2013 approved by LSC the significant part of work is planned for the autumnal period and thus it is just about to be started. We will host four colleagues at CHMI in Prague within the frame of RC LACE, two of them being from the HIRLAM partner institutes. The cooperation between RC LACE and HIRLAM has continued in the first nine months of 2013 and it is planned to continue in the future. A considerable part of work (mainly connected to the study of diffusion and turbulence) has been shifted to the forthcoming time periods mostly due to the unavailability of the allocated manpower. Nevertheless, considering the substantial progress made in the physical parameterization topics being solved by the same workforce, we expect the work in dynamics will start soon.

Concerning topics we have tackled in 2013, the other topics are outbalanced with the implementation of finite element method in the vertical discretization of the fully compressible equations (VFE NH), where the breakthrough from the end of the last year has been followed by thorough tests of the whole scheme behaviour. The implementation is expected to be phased during autumn to the official ALADIN/ARPEGE cycle to be available at the beginning of 2014 (cy40t1). In cooperation with colleagues from Météo France and ECMWF, we expect to adapt the implementation for the use in the global model. For the model ARPEGE using the stretching and even for ALADIN application on large domains where the linearization may not be done with a constant mapping factor the harmonization with the option LSIDG/LESIDG allowing horizontally varying mapping factor in the linear model is needed. A contribution to the ALADIN/HIRLAM Newsletter has been prepared describing finite element method used and summarising results of idealized tests and real case experiments achieved. A summarising paper is expected to be written during autumn for further publication.

Some tests of AROME with 3DVAR were prepared for the comparison of the Météo-France and the OMSZ SLHD settings. A small part of the verification is complete; a bigger part is still to come. The work will continue in the forthcoming period.

Another comparison study was prepared related to the rapid changes in the surface pressure field based on the so called MCUF field. This characteristic is contained in the ARPEGE LBC files, but not in the IFS ones. A new method to calculate such characteristic by an ALADIN model run from IFS LBC files was proposed. Then the results were compared for ARPEGE and IFS coupling for a long period and the common LACE domain. Some problems of the proposed method were identified and new directions of the research were proposed. Some conclusions were carried out for positioning of the Croatian application coupling zone. This

work has been done in the first months of 2013 and was already mentioned in the updated report of Working Area Dynamics&Coupling from March 2013.

Scientific and technical main activities and achievements, major events

Task 1. VFE NH

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

Description and objectives: To design a stable and robust vertical discretization based on the finite elements method (VFE) in the non-hydrostatic dynamical kernel of model ALADIN as an extension to the one which has been implemented into the hydrostatic dynamics of the IFS/ARPEGE/ALADIN code; to implement the proposed method into the code of ALADIN model and to prepare the code to be used in high resolution real simulations with orography with the expected benefit being the enhanced accuracy for the same vertical resolution when compared with vertical finite differences (VFD) method; to run a wide range of tests of the proposed scheme in idealized and real simulations to study the behaviour of the proposed scheme and to validate its stability and accuracy properties; to run similar tests to validate the convergence of the SI solver with the proposed method and to establish the speed of convergence if possible.

Executed efforts: JV - 2 month (local work), PS – 3 months (local work); total 5 months

Estimated efforts: JV – 3.5 months (2 month of local work, 1.5 months - LACE stay at CHMI, Prague), PS – 4 months (local work), JS – 0.5 month (LACE stay at CHMI, Prague), AS – 1 month (LACE stay at CHMI, Prague); total 9 months

Contributors: Jozef Vivoda (Sk), Petra Smolíková (Cz), Juan Simarro (HIRLAM Es), Alvaro Subias (HIRLAM Es)

Documentation: a contribution to the ALADIN/HIRLAM Newsletter, August 2013; reports from stays (3x), draft of paper for further publication

Status: This strategic topic is being solved for several years in frame of ALADIN community. An independent research has been held in frame of HIRLAM (AEMET) and ECMWF. Collaboration between ALADIN and HIRLAM was established in 2012 and has continued in 2013. An intensive common work is planned for autumn 2013 when 2 colleagues from AEMET (Spain) will stay in Prague jointly with LACE people.

At the end of 2012 we succeeded in preparation of a working implementation of VFE scheme to NH dynamics under the cycle CY36t1 with promising stability properties approved in preliminary 2D vertical plane tests. The cornerstones of this implementation are: new definition of vertical parameter η, new definition of knots used in the construction of B-spline basis functions, new definition of vertical operators for integration and derivation. The

vertical operators are defined in several versions with properly posed boundary conditions. At each place where they appear in the equations, the proper version of the vertical operator is applied. For transformations between vertical divergence variable d used in the SI scheme (linear model) and vertical velocity variable w used in the non-linear model under the option LGWADV, we keep the finite difference operators.

Contrary to the hydrostatic equations where only integral vertical operators appear, and to the fully compressible system of equations cast in the height based coordinate where only derivative vertical operators occur (according to Simarro and Hortal) in the fully compressible Euler equations of ALADIN-NH designed for the mass based vertical coordinate of Laprise appear both, the vertical integral operator, the first and the second derivative vertical operators.

Moreover, a set of constraints fulfilled by continuous vertical operators was found to be crucial for stability and those relations were carefully introduced in the FD formulation of vertical discretization. The fact that these constraints are not satisfied in FE approach has consequences in the design of implicit part of the time scheme and it was necessary to check its influence on stability of the whole model. In particular, it is not possible to eliminate all the variables but one and get a single structure Helmholtz equation in the implicit part of the time scheme. We abide with the system of linear equation for two variables which we solve with a stationary iterative method with predictor being solved as if the given constraint was satisfied. We show that our solution converges in all tested idealized and real cases and one iteration of the implicit solver is enough to reach satisfying results. The computational price to be paid remains in percent units and does not penalize the whole integration significantly. However, a harmonization of the proposed FE method for vertical discretization with the iterative solution to the implicit problem needs further investigation.

When implementing the FE method in the non-hydrostatic ALADIN model, we aimed at the comparable stability properties as for the FD method in both idealized experiments and real simulations. Moreover, similarly as in the hydrostatic case we expect enhanced accuracy. A set of test cases has been run in the 2D vertical plane version of ALADIN-NH, including potential flow, the non-linear non-hydrostatic flow over idealized orography and the density current test published by Straka. These experiments proved the satisfactory accuracy properties of the proposed scheme and they showed that the FE NH dynamical core is as stable as the finite difference one when using the iterative centred implicit time scheme with one iteration (predictor-corrector scheme). Further, adiabatic academic experiments were prepared in 3D with horizontal wind perpendicular to the Alps ridge and 1km resolution. Again no sign of stability problems was detected.

Moreover, 3D diabatic experiments were performed with model horizontal resolution of 2.2km over the Central Europe domain covering Alps. The objective scores were neutral to the change of vertical discretization in all tested cases. A slight shift of the precipitation

amounts to higher intensities was observed with the FE method used, especially in the summer period. These experiments will be repeated and enhanced after VFE will be available in the new cycle cy40t1 of ALADIN-NH.

The proposed FE method was implemented with the general order of B-splines. So far all tests were restricted to the cubic B-splines only. Nevertheless, we plan to study the influence of the B-spline order on the accuracy and the time stepping stability of the whole system. Further, we plan to extend the designed FE vertical discretization scheme into the dynamical core of the global model ARPEGE/IFS.

The current implementation is expected to enter the official ALADIN code (cy40t1) at the beginning of year 2014. (Phasing is planned for October, November 2013.)

Task 2. Physics-dynamics interface

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.

Executed efforts: none

Estimated efforts: 1 month (LACE supported stay at CHMI, Prague)

Contributors: David Lancz (Hu)

Documentation: report (published on the LACE web page, section D&C)

Status: NOT YET STARTED; PLANNED FOR NOVEMBER 2013

Subject: 2.2 Application of ENO techniques 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.

Executed efforts: none

Contributors: Ján Mašek (Cz)

Documentation: none

Status: POSTPONED TO 2014
Opening of this subject was conditioned (for reasons of workforce availability) by the finalization of work on the radiation scheme (see Physics Working Area report) which is felt to be more urgent.

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.

Executed efforts: none

Contributors: Radmila Brožková , Ján Mašek (Cz)

Documentation: none

Status: POSTPONED TO 2014
Opening of this subject was conditioned (for reasons of workforce availability) by the finalization of work on the radiation scheme which is felt to be more urgent.

Subject: 2.4 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.

Executed efforts: 1 month (local work, OMSZ)

Estimated efforts: 1.5 months (local work, OMSZ)

Contributors: Balazs Szintai (Hu)

Documentation: results description, available on demand

Status: A one-month summer period with frequent convection events (May 2013) of AROME forecast was run over the Hungarian operational domain with horizontal resolution 2.5km, where the Météo-France (MF) and the HMS SLHD settings were compared. The original MF setting applies SLHD on falling hydrometeors, while no SLHD is applied on wind and temperature, while the new HMS setting does the opposite – SLHD applied on wind and temperature and no SLHD for falling hydrometeors. Initial conditions are the same for the two experiments. Namely, the Hungarian operational AROME 3DVAR (using the HMS SLHD settings). The verification takes into account only stations bellow 400m. Results achieved show:

- positive impact of HMS settings on mean 10 m wind and wind gusts as compared to MF settings
- positive impact of HMS settings on precipitation (for a summer period with convection)
- neutral impact on 2 m temperature and humidity.

For the end of 2013 more verifications are planned, especially with the SAL object oriented precipitation verification against radar measurements.

Task 3. 1D2D turbulence scheme for ALARO

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.

Executed efforts: none

Contributors: Ján Mašek (Cz)

Documentation: none

Status: POSTPONED TO 2014
The work has not been started yet for similar reasons as in Task 2.

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.

Executed efforts: none

Contributors: Ján Mašek (Cz)

Documentation: none

Status: POSTPONED TO 2014
The work has not been started yet for similar reasons as in Task 2.

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.

Executed efforts: MT - 2 months (local work)

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

Contributors: Martina Tudor (Cr)

Documentation: report, available on demand

Status: The topic was being solved mainly in the first quarter of 2013 and results achieved were already summarized in report from 2012 issued in March 2013. We describe them here in short.

Operational LBC data are provided to LAM with time interval of several hours (typically 3h). These data are used at lateral boundaries of the LAM domain every timestep of several minutes. Consequently, LBC data of the large scale model are (linearly) interpolated in time. The interpolation procedure distorts the model fields and can lead to LAM forecast failures in case of fast propagating storms.

In order to monitor the occurrence of potential LAM forecast failures due to inadequate coupling update frequency, a recursive high-pass filter has been implemented to the ARPEGE model and applied to the surface pressure field. Large values (above a given threshold value) of the filtered surface pressure (MCUF) field indicate a rapidly moving disturbance (a storm) in the surface pressure through the corresponding model grid point. If this grid point lies

inside the coupling zone of the LAM, it can be expected that the LAM forecast will miss the storm due to time interpolation of boundary data.

The analysis of the MCUF field from ARPEGE coupling files for the common LACE coupling domain shows that this field is above the threshold far more frequently than acceptable. The conclusion was drawn that Western Mediterranean appear to be an area where storms frequently propagate with high velocities and it must not be resolved in LBCs.

In case that LBC files for the coupling of the LAM are taken rather from IFS (ECMWF) then from ARPEGE, one has to solve similar problems. Since the MCUF field is not provided by ECMWF in the coupling files of IFS, a new method for MCUF calculation was proposed requiring low resolution (15.4km) run of ALADIN model on the domain of the LBC files. Then an analysis of the MCUF field was prepared for a two months period. This analysis has indicated which areas should be avoided as parts of the coupling zone. The proposed method is however computationally expensive and has some weaknesses, as the following: different model dynamics used lead to different MCUF values computed; a quickly moving storm may remain undetected by MCUF calculation; the resulting MCUF field shows suspiciously low cyclonal activity on the western Mediterranean comparing to the results from ARPEGE.

We expect that work will continue in 2014.

List of actions, deliverables including status

Task 1. VFE NH

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

Deliverables: contribution to the ALADIN/HIRLAM Newsletter, August 2013, report from stays (3x), draft paper for further publication, code modification prepared for phasing to cy40t1

Status: ONGOING

Task 2. Physics-dynamics interface

Subject 2.1: Feasibility study to add the physical tendency of vertical velocity to the adequate prognostic (NH) variable

Deliverables: report from stay

Status: PLANNED FOR NOVEMBER 2013

Subject 2.2: Application of ENO technique to semi-Lagrangian interpolations

Deliverables: no

Status: POSTPONED TO 2014

Subject 2.3: Design of the ideal share between the horizontal turbulence and numerical diffusion depending on the scale

Deliverables: no

Status: POSTPONED TO 2014

Subject 2.4: Impact of horizontal diffusion (SLHD) in AROME with 3DVAR

Deliverables: results summarisation, available on demand

Status: ONGOING

Task 3. 1D2D turbulence scheme for ALARO

Subject 3.1: Scientific validation

Deliverables: no

Status: POSTPONED TO 2014

Subject 3.2: Tests in <1 km resolutions

Deliverables: no

Status: POSTPONED TO 2014

Task 4. LBC coupling strategy

Subject: Rapid changes in surface pressure field

Deliverables: progress report, available on demand

Status: ONGOING, an analysis of the MCUF field was prepared for both the ARPEGE and the IFS coupling files on the common LACE domain; problems and weaknesses of the proposed methods were formulated.

Documents and publications

1) J.Vivoda, P. Smolíková, *Finite elements used in the vertical discretization of the fully compressible forecast model ALADIN-NH*, ALADIN/HIRLAM Newsletter, August 2013.

2) M.Tudor, *Monitoring the coupling update frequency on the LACE coupling domain in LBC files from ECMWF*, available on demand.

3) Reports from stays (autumn 2013)

Activities of management, coordination and communication

1) Joint 23nd ALADIN Workshop & HIRLAM All Staff Meeting, 15-19/04/2013, Reykjavik, Iceland (participation of Petra Smolíková – presentation "LACE – dynamics and coupling", Jozef Vivoda – presentation "Vertical finite elements in the NH dynamical core of ALADIN")

2) 10th International SRNWP-Workshop on Nonhydrostatic Modelling, 13-15/06/2013 Offenbach, Germany (participation of Petra Smolíková, poster "Model ALARO with NH dynamics in convection permitting scales")

3) 35th EWGLAM and 20th SRNWP Meeting, 30/09-3/10/2013, Antalya, Turkey (participation of Petra Smolíková, presentation "LACE news in dynamics - finite elements in vertical discretization of ALADIN NH")

LACE supported stays – 4 person/months in 2013

1) Jozef Vivoda (SHMI, Slovakia) – 1.5 months in Prague (CHMI), October-November 2013

2) Juan Simarro (HIRLAM/AEMET, Spain) - 0.5 month in Prague (CHMI), November 2013

3) Alvaro Subias HIRLAM/(AEMET. Spain) - 1 month in Prague (CHMI), October 2013

4) David Lancz (OMSZ, Hungary) – 1 month in Prague (CHMI), November 2013

Summary of resources/means

The total effort invested to the area of Dynamics&Coupling in frame of LACE in 2013 is estimated to be 11 person/months, half of which was already executed up to the September 2013, 4 person/months are planned to be executed in autumn and supported by LACE budget directly.

Task	Resource			LACE stays	
	Planned	Executed	Estimated	Executed	Estimated
VFE NH	6	5	9	0	3
Phys-dyn interface	5.5	1	2.5	0	1

1D2D turbulence scheme	2.5	0	0	0	0
LBC coupling strategy	2	2	2	0	0
Total	**16**	**8**	**13.5**	**0**	**4**

The problem with no availability of the required workforce persists. With the workforce disposable we expect to be able to cover nearly 85% (13.5 person/months instead of 16 person/months) of means planned for 2013 (till the end of the year) with little shifted priorities. In first 8 months we have covered half of the planned work. We strengthened the efforts in the first topic (VFE in NH) and reached substantial progress, while in part of topics 2 and 3 we must wait until the work will be finished on other more urgent topics (mostly from the Working Area of Physics). Hence the work on these subjects is left for 2014. On the other hand, we believe that with the progress made on the subject in the area of Physics, we may expect an improvement of the situation in the next year. For LBC coupling strategy, we accomplished the planed tasks. The continuation of work on this topic is questionable for the reason of just started maternity leave of the dedicated person (M.Tudor).

Problems and opportunities

We can just repeat what was written in the report for 2012, the description of problems and opportunities we have did not develop in 2013 with the exception of participation of more people from distinct countries (Hungary, Croatia, Spain (HIRLAM)):
“As often repeated, in the long term we suffer from a lack of available workforce from the members of LACE. It showed out that the transition of people from dynamical topics to issues in other areas which are felt to be more urgent (i.e. radiation scheme) and the drain of people in vicinity of an exigency to guarantee the continuation of operational production persists in this period. No issues in the area of Dynamics&Coupling are considered as really pressing since the horizontal resolutions around 1 km are reached. But there are challenging tasks requiring a long-running ambition which we are attacking already for some time or which we would like to tackle. We believe that in the longer term we have to maintain our knowledge and skills in the area of Dynamics&Coupling and continue the research leading to a dynamical kernel prepared for very fine resolutions. We would felt as an extreme detriment if our engagement in these tasks would be endangered by non-availability of desirable workforce. Hence a retrieval of appropriate candidates for research in the area of Dynamics&Coupling is understood as crucial for continuation of planned actions.”