Working Area Dynamics & Coupling

Progress Report

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Progress summary

In the working plan for LACE area of Dynamics&Coupling approved by LSC we focus on three main topics, all of them being rather long-term: NH VFE, physics-dynamics interface and 3D turbulence. Even this rather condensed scope was not possible to fully cover with the available manpower this year. However, some candidates were found for open topics and we expect the start of the respective work during 2013. Cooperation with HIRLAM consortium was established during 2012 which appeared to be very fruitful and inspiring and a stay of Juan Simarro (AEMET) was executed at CHMI (Prague) on the LACE behalf.

In designing vertical finite elements scheme for NH dynamics, most attention was paid to vertical levels distribution and to correct formulation of top and bottom boundary conditions for vertical integral and derivation operators. In consequence, a version of VFE discretization in NH dynamics was implemented showing very promising stability properties demonstrated in academic tests with vertical plane (2D) model.

For physics-dynamics interface the second order accurate scheme based on SETTLS technique was implemented and tested, unfortunately with the conclusion that this method does not provide sufficient stability, but shows strong time oscillations in the moisture and temperature fields. The new SLHD tuning for AROME model prepared with the aim to improve precipitation forecast was tested in a suitable case study and with objective scores. The new SLHD setting was found to be beneficial in most of the parameters. The study will continue in 2013.

Several partners (Hu, Cr) were active in revisiting the coupling strategy of model AROME and ALARO to the leading model. Hence 2 new subtopics have emerged as interesting in this area. The AROME dynamical adaptations coupled to either ALARO LBC files, or to IFS ones, were being compared on the Hungarian operational domain with the conclusion that the IFS coupling provides better results in most of the parameters. Based on this study, the coupling of AROME to IFS was introduced in OMSZ in December 2012.

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.

On top of that, we opened a new topic connected to the sensitivity of model results to the length of the time step used. A study of model behaviour was prepared, unfortunately with no clear indication of problem sources.

Scientific and technical main activities and achievements, major events

VFE NH

Action/Subject/Deliverable: Vertical finite element scheme for NH dynamics

Description and objectives: To design a VFE scheme for NH dynamics as an extension to the one which has been implemented into the hydrostatic dynamics of the IFS/ARPEGE/ALADIN code; to implement it into the code of ALADIN; to prepare a detailed analysis of its stability properties (theory, 2D vertical plane tests).

Efforts: JV - 2.75 months (with LACE support), JS – 0.5 month (with LACE support), PS – 1.75 months (local work); total 5 months

Contributors: Jozef Vivoda (Sk), Juan Simarro (Hirlam), Petra Smolíková (Cz)

Documentation: report from stay of JS, available on demand

Status: This strategic topic is in frame of ALADIN community being solved under the LACE auspices for several years. Advanced and up to now independent research has been held in frame of HIRLAM (AEMET). This year collaboration between these two groups was established which was realized by 3 scientific stays (1 from HIRLAM, 2 from LACE) in Prague (CHMI). Since this collaboration was found to be interesting and productive from both sides the intention has arisen to continue with it in the future.

The working implementation of VFE scheme to NH dynamics is prepared under the cycle CY36t1 which allows running tests in vertical plane tool (2D model). The already performed tests have shown significant stability of the proposed method. Considerable efforts were concentrated to the vertical discretization and its role for the stabilization of the whole VFE scheme. An attempt has been made to investigate stability of the VFE scheme analytically in Mathematica software by developing a relation between the breakpoints position and eigenvalues of the vertical operators. This attitude appeared to be not tractable even in the most simplified context (minimum number of vertical levels used in which the model discretization may be expressed being 5, symmetrized position of breakpoints etc.).

Then attention was paid to correctly set the top and bottom boundary conditions for distinct terms on which either integration, or derivation in the vertical is applied. For distinct terms, various vertical operators were developed with well posed boundary conditions. Hence, a fundamental progress has been made by achieving a stable configuration for 2D testing. In such a configuration very tough tests were performed as non-linear non-hydrostatic flow over Agnesi shaped mountain of Bubnová (1995) and the so called Straka test (1993). It was shown that this configuration with VFE scheme is robust enough to sustain the integration for a reasonable time.

In the current (VFD) architecture of the NH model, the SI scheme in the discrete context is based on the algebraic elimination of all variables but one (namely d), in order to reach a single "discrete structure equation" (Helmholtz equation) solved in the spectral space. For this algebraic elimination to be possible, a mathematical constraint (C1) must be satisfied. This constraint is not necessarily fulfilled for the VFE discretization. Fortunately, the implicit problem in discrete form is just a linear inversion, and could be performed with the couple of two variables (namely D,d) for which the SI operator is inverted. Then the constraint (C1) does no longer need to be fulfilled and the system of 2L equations could be solved. It is twice as large as for the hydrostatic case, but in terms of computing time it does not constitute a problem because the inversion of the coefficient matrix may be performed only once in the model's setup. However, this inversion may not be done for the case of horizontally varying map factor linearization (the namelist switch LESIDG). For this reason an iteration method was designed to solve the implicit problem. The convergence of the proposed method was studied which showed the correct behaviour of the scheme. The convergence was assured for all cases which were found stable.

From the HIRLAM part there was an extensive research of models with distinct choices of parameters made than in ALADIN model (mainly alternative set of prognostic variables and height based vertical coordinate). Nevertheless, it was concluded that the promising choice of height based vertical coordinate is not favourable to pressure based one in case of VFE discretization with steep orography.

Physics-dynamics interface

The physics-dynamics interface couples the physics parameterizations to the dynamical core. With the interconnection of different model physical packages (AROME, ALARO, HIRLAM) some convergence actions were needed for harmonization between these models. The dynamical core may be also considered as multiplicated by different features (hydrostatic versus fully elastic). The need to be able to operate the same model on distinct resolutions calls again for higher flexibility of the physics-dynamics interface. Various topics have emerged from these demands as:

Action/Subject/Deliverable: Higher accuracy time scheme

Description and objectives: To implement and test the second order accurate coupling scheme of physics to dynamics based on the SETTLS type technique.

Efforts: 2 months (local work)

Contributors: Petra Smolíková (Cz)

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

Status: The current explicit first order in time accurate coupling of physics to dynamics was easily extended to second order accuracy by using the SETTLS type technique (ClearCase

branch at CHMI). The theory in this case says that we will lose little bit on stability but gain on accuracy. However, the real case simulations with the settings used in the current operational version of the model ALARO for the Czech domain showed poor stability of this configuration. If the SETTLS type coupling is applied on moisture significant time oscillations appear in the field of temperature mostly near the ground, but not exclusively restricted to this area.

If applied only on prognostic GMV variables as temperature and horizontal wind components, the stability was recovered but the expected enhanced accuracy was not detected in a one month validation (the forecast for 54 hours once per day). We conclude from these tests that we shall stay with the current explicit technique and we resign for the time being on the second in time accuracy. This topic was a continuation of work started at 2010, it is considered as closed now.

Action/Subject/Deliverable: 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 aim of the topic is to propose a solution, to implement it in the code of ALADIN/ALARO and to test it in appropriate conditions.

Efforts: none

Contributors: none

Documentation: no

Status: POSTPONED TO 2013

An appropriate candidate was found for this task (D.Lancz - Hu) available during 2013. The realization of work was postponed to 2013.

Action/Subject/Deliverable: 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.

Efforts: none

Contributors: none

Documentation: no

Status: POSTPONED TO 2013
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 is postponed to 2013. One short stay of Ján Mašek is planned at the end of year to start an analysis of the problem which will allow a better planning of future work.

Action/Subject/Deliverable: Impact of horizontal diffusion (SLHD) in AROME

Description and objectives: The SLHD option was tuned for AROME with the aim to improve precipitation forecasts. As the default configuration in AROME, the non-linear, flow dependent Semi-Lagrangian horizontal diffusion (SLHD) is applied to all (falling and non-falling) hydrometeors. However, experience shows that AROME tends to overestimate precipitation maximum and wind gusts in strong convective cells. It was assumed that changes in the horizontal diffusion scheme might have a beneficial impact on these problems. Following the work of Bengtsson et al. (2012), SLHD was applied to all dynamical fields (temperature, wind, water vapour), but not to falling hydrometeors („AROME_new" experiment). Additionally, the supporting spectral diffusion was switched off below 100 hPa. These new settings are operational at the Hungarian Meteorological Service since July 2011. The aim of this topic was to prepare a case study and a long period study based on objective scores to test the new SLHD settings.

Efforts: 1 month (local work)

Contributors: Balazs Szintai (Hu)

Documentation: no

Status: In the frame of this topic, a case study was accomplished for an anticyclonal situation with heavy thunderstorms in the evening over the eastern part of Hungary. The application of the new SLHD settings reduces both the maximum precipitation and the wind gusts associated with convective cells. Next to the case studies, a one month period has also been investigated with objective scores. In this verification method model fields and observations were first upscaled to 13 larger regions covering Hungary. The conclusions are as follows: The SLHD modification slightly deteriorates temperature, has neutral impact on precipitation and wind speed, and significantly improves the wind gust forecasts.

An important characteristic in forecasting heavy precipitation events is the ability of the NWP model in forecasting the timing of convection. For the one-month period the simulated diurnal cycle of precipitation was compared to radar measurements. Models with a parameterized deep convection (ECMWF/IFS, ALADIN) initiate convection too early. The AROME model with resolved deep convection performs much better in this respect. The AROME run with default SLHD settings overestimates the precipitation peak in the late afternoon. The experiment with new SLHD settings corrects this overestimation; however, precipitation is now underestimated during the night.

Results described above were performed with AROME driven by the operational ALADIN model, using the old deep convection scheme. However, since March 2012 the hydrostatic 8 km model of OMSZ is using the ALARO physics. Experience during the convective season of 2012 showed that the operational AROME model (using the ALARO LBCs and the new SLHD settings) tends to seriously overestimate the convective precipitation amounts. Consequently, the SLHD tuning experiments have been revisited, and the first preliminary results show that in the case of using ALARO (or ECMWF/IFS) LBCs, the new SLHD settings might not be as beneficial as seen for previous experiments. The work is currently in progress.

Action/Subject/Deliverable: Sensitivity of model results to the time step choice

Description and objectives: In the past months, a significant sensitivity of model results to the choice of the time step length has been found in the operational and parallel suites at CHMI; especially, in the starting time of the convection activity and in the field of cumulated precipitations. Similar problem has been reported by other national services as well. The task was a proper formulation of the problem, its demonstration in real simulations and an attempt to find sources of the observed sensitivity. The question has arisen, how strong dependence of model results on Δt is acceptable. Do we expect only unchanged bias of model variables, or shape preservation of plotted fields (for cumulated precipitations), or exact consistency of all fields?

Efforts: 0.5 month

Contributors: Ján Mašek (LACE supported stay at SHMU)

Documentation: no

Status: It was demonstrated that model results are sensitive to even very small change in Δt (from 144s to 150s, which corresponds to 25, 24 steps per hour respectively). Furthermore, the sensitivity persists for the lengths of the time step allowing the use of Euler advection (around 30s) confirming non-convergence of the solution.

The suspicion that the diffusion (either spectral, or SLHD) may be responsible for the problem has not been confirmed. One of the possible sources of the problem could be seen in the physics-dynamics interface. No facility was found to confirm or refuse this suspicion. Tests in adiabatic hydrostatic conditions were prepared demonstrating that the problem does not disappear even in this simple context. It was demonstrated that the change of SL extrapolations (SETTLS, or NESC PC with 1 iteration) gives feedback of the same magnitude as the change of the time step to its half-length.

When moist physics is employed, the effect is strengthened. On the other hand, the change in used physical package from “new” to “old” microphysics (LSTRAPRO, or LSTRA key) has much stronger impact then the change of the time step used. No clear conclusions were

drawn up; we expect to observe the behaviour of the model with respect to the described problem on longer term.

As a side effect, a bug in VFE design for 3TL SL scheme in hydrostatic adiabatic regime has been reported. The exact source of it remains unknown.

3D turbulence scheme

Action/Subject/Deliverable: Validation and testing

Description and objectives: This subject covers development of the specific approach to the 3D turbulence (or perhaps better called 1D+2D turbulence) designed for NWP model (being far from computed with isotropic grid) for anticipated resolutions between 500 m and few km of horizontal mesh. It is assumed that after the validation of the scheme present implementation, some specific (academic) cases will be studied in order to better understand the extra features offered by this new scheme, then the most appropriate tuning for (numerical) horizontal diffusion in the presence of the horizontal turbulence scheme will be done.

Efforts: none

Contributors: none

Documentation: no

Status: POSTPONED TO 2013
The work has not been started yet for similar reasons as in (2c). However, the present status is such that a research version of the 3D turbulence scheme is prepared in the code under the key L3DTURB. A new key LTDIABLIN was introduced which enables the choice of horizontal Laplacian being applied only on the variable while its physical tendency is interpolated separately. Some actions are expected in 2013.

Coupling strategy

Action/Subject/Deliverable: The choice of a leading model for AROME integration

Description and objectives: In case of AROME model used as the LAM model, there is a natural choice between two possible leading models for coupling: ALARO on lower resolution than the incorporated AROME, or ARPEGE (IFS). The aim of this task was to provide a comparison study for these two options.

Efforts: LK - 2 weeks, BS - 2 weeks, GB - 3 weeks; total 1.75 months (local work)

Contributors: László Kullmann (Hu), Balázs Szintai (Hu), Gergely Bölöni (Hu)

Documentation: report on verification results, on demand

Status: On Hungarian operational domain a one month period (25th June 2012 - 25th July 2012) experiments of AROME dynamical adaptation coupled both to ALARO and to IFS with a 1 hour update frequency were performed with the following results. For the upper air variables (for longer than 6 hour range) the IFS coupling provides better results with the exception of wind bias. Also precipitation may be slightly improved with IFS coupling in object based verification. SAL shows a better structure and location with ALARO coupling but a bit better amplitude with IFS coupling. Based on these results, the coupling of AROME to IFS was introduced operationally in Hungarian Meteorological Service in December 2012.

Action/Subject/Deliverable: Coupling strategy with regard to rapid changes in surface pressure field

Description and objectives: 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.

An analysis of the MCUF field from ARPEGE and ALADIN (based on IFS) coupling files for the common LACE coupling domain is expected leading to a recommendation on the positioning of the coupling zone for the Croatian operational application or any other application in LACE.

Efforts: 2.75 months (local work)

Contributors: Martina Tudor (Cr)

Documentation: report, available on demand

Status: 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 of a 8 km resolution LAM when provided with 3 hour interval. In LAM with roughly 3 times larger horizontal resolution, even 1 hour coupling interval would be insufficient.

There is an intention in Croatia to couple the 00UTC run rather to IFS starting from +06 forecast of the 18UTC run. 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, 4 times a day and up to +78. Then an analysis of the MCUF field was prepared for the period from 1st Nov 2010 to 31st Dec 2012. This analysis has indicated which areas should be avoided as parts of the coupling zone (La Manche, North Sea, Baltic Sea, western shore of Black Sea, and the lee of the Alps).

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.

An alternative to the proposed method is to compute the MCUF field in operational IFS and provide it in LBC files.

List of actions, deliverables including status

Subject: VFE NH

Deliverables: report from the stay of JS, available on demand

Status: ONGOING, working version of the code under cycle 36t1ope (ClearCase branch at CHMI), 2D experiments in different regimes (NLNH flow over orography, potential flow, Straka's cold potential temperature bubble test) and for different vertical discretizations

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Subject: Higher accuracy time scheme - research, design, testing

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

Status: FINISHED, the proposed scheme based on the SETTLS technique has poor stability properties

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

Deliverables: no

Status: POSTPONED TO 2013

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

Deliverables: no

Status: POSTPONED TO 2013

Subject: Impact of horizontal diffusion (SLHD) in AROME

Deliverables: no

Status: ONGOING, a case study and an objective scores verification study was prepared to compare the new SLHD setting with the previous one

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Subject: Sensitivity of model results to the time step choice

Deliverables: no

Status: FINISHED, the problem was demonstrated and better described

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Subject: 3D turbulence scheme

Deliverables: no

Status: POSTPONED TO 2013

Subject: The choice of a leading model for AROME integration

Deliverables: report on verification results, available on demand

Status: FINISHED, a comparison study was prepared

Subject: Coupling strategy with regard to 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.Simarro, *Estancia de Juan Simarro en el Instituto Meteorológigo Checo durante los días 4 a 17 de Abril de 2012*, report from the stay, English version, available on demand.

2) P. Smolíková, *Second order accurate time scheme for the physics-dynamics interface based on SETTLS technique*, available on the LACE web page.

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

Activities of management, coordination and communication

1) Joint 22nd ALADIN Workshop & HIRLAM All Staff Meeting 2012, 7-10/05/2012, Marrakech, Morocco (participation of Petra Smolíková)

2) 34th EWGLAM and 19th SRNWP Meeting, 8.-11.October 2012, Helsinki, Finnland (participation of Petra Smolíková, presentation "Recent developments related to dynamics in the LACE consortium")

LACE supported stays – 3.75 person/months in 2012

1) Juan Simarro (HIRLAM/AEMET) - 0.5 month in Prague (CHMI), April 2012

2) Jozef Vivoda (SHMI) – 2.75 months in 2 stays in Prague (CHMI), April, October-December 2012

3) Ján Mašek (CHMI) – 0.5 month in Bratislava (SHMI), December 2012

Summary of resources/means

The total effort invested to the area of Dynamics&Coupling in frame of LACE in 2012 is 13 person/months, 3.75 person/months being supported by LACE budget directly.

Subject/Action/ Deliverable	**Resource**		**LACE stays**	
	planned	**realized**	**planned**	**realized**
VFE NH	4	5	2.5	3.25
Phys-dyn interface	6	3.5	1.5	0.5
3D turbulence	2	0	0	0
Coupling strategy	0	4.5	0	0
Total	**12**	**13**	**4**	**3.75**

With the available workforce we were able to cover only nearly 70% (8.5 person/months instead of 12 person/months) of means planned for 2012 for the first three topics and the

coverage of subjects was partially shifted. Some work is left for 2013. On the other hand, the coupling strategy of limited area model to the leading model was revisited on top of the expected activity in the D&C area. The final expected efforts spent in 2012 exceed slightly the planned amount of work.

Problems and opportunities

As often repeated, in the long term we suffer from a lack of available workforce from the members of LACE. Even in the planned efforts for year 2012, only contributors from Cz and Sk were expected. 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.