Working Area Dynamics & Coupling

# Progress Report

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| **Prepared by:** | Area Leader Petra Smolíková |
| **Period**: | 2018 |
| **Date**: | 6/3/2019 |

## Progress summary

This report summarizes the work done in the Area of Dynamics and Coupling of RC LACE during 2018 with the emphasis on the second half of the year.

## 1. Scientific and technical main activities and achievements

Let us mention the biggest achievements in the tasks planned for the year 2018.

## Task 1. VFE NH

**Subject:1.1 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 difference (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).

**Status:** Phasing to CY45T1 was finished in November 2017. The content of the branch covers the work done in 2014-2017. This year we finished the review process of a paper submitted to MWR. We planned to revisit the Helmholtz solver and study the compatibility of direct inversion done after elimination of all variables but horizontal divergence (solution proposed by Voitus) with finite element vertical discretization. This work needs to wait till the Helmholz solver elimination is implemented by Fabrice Voitus, probably in the next model cycle.

The designed finite element operators for vertical integral of a general order were tested in hydrostatic context to see if their behaviour is beneficial compared to the cubic vertical integral previously implemented in ECMWF. We have difficulties to find an appropriate testing environment. In real 3D cases, we found that the new integral operators with higher accuracy order may sharpen the maxima of predicted cumulated precipitation but it is hard to check if it corresponds to the reality. We compared the obtained values to measured radar reflectivity. See Fig.1 for an illustration of results.

We noticed that there is a zig-zag structure in dynamical tendencies of enthalpy observed in the DDH diagnostic tool close to the domain top (approximately from 200hPa); see Fig.2.

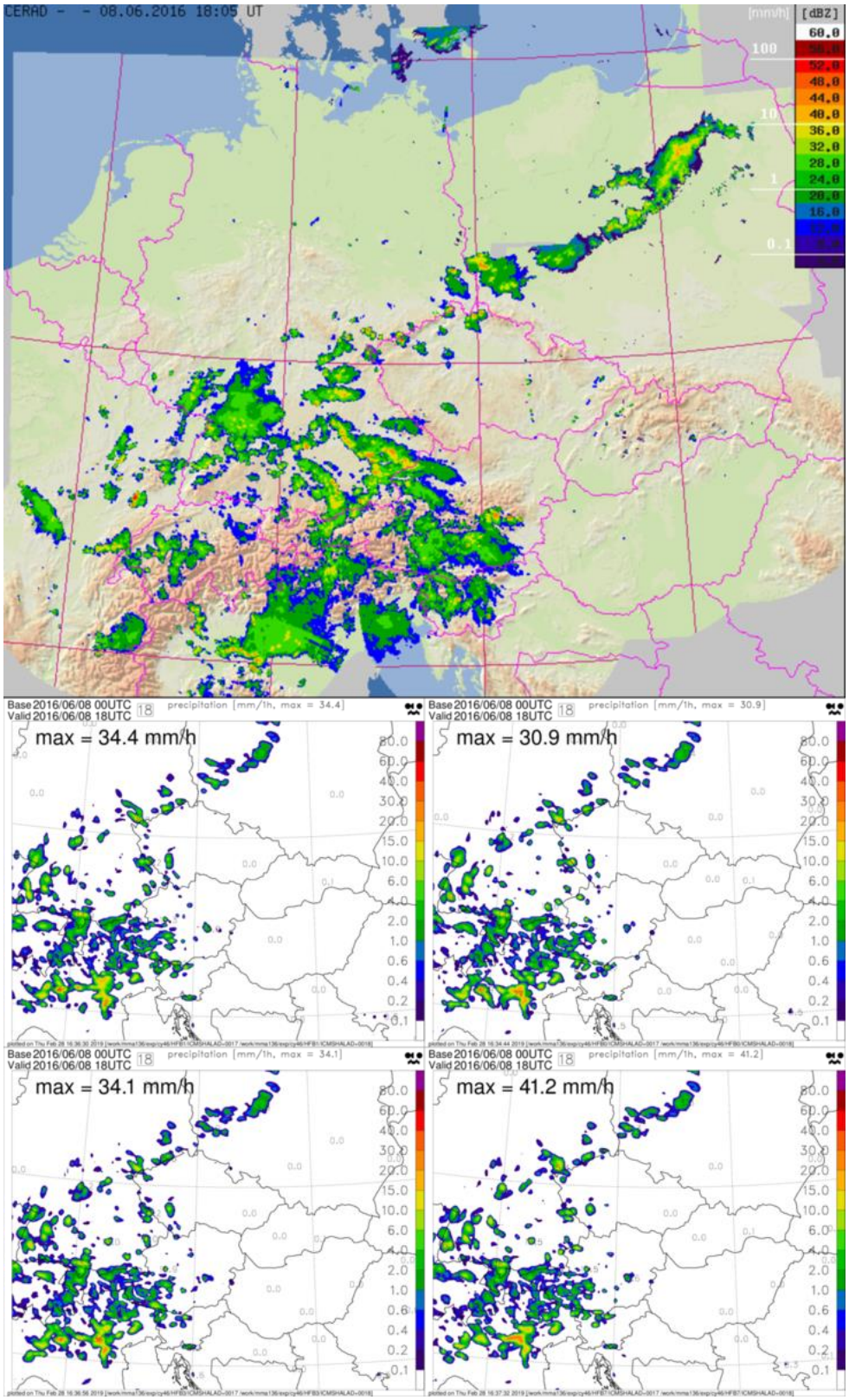
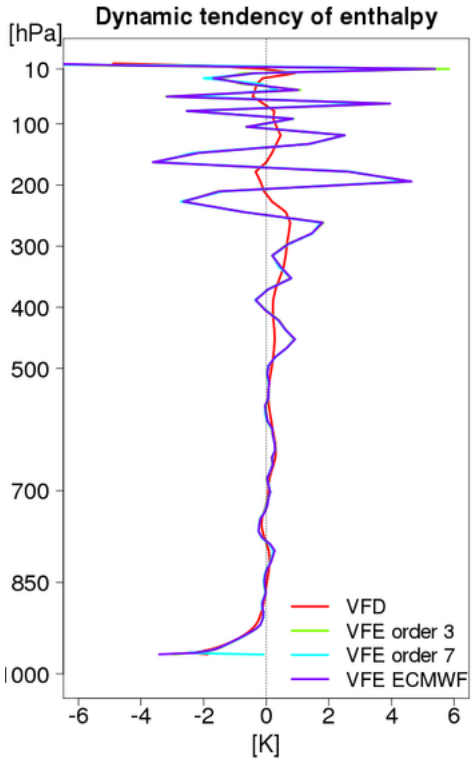



*Figure 1: Precipitation cumulated from 17 to 18 UTC, 8 June 2016, forecasted with dynamical adaptation of ALARO at 2km horizontal resolution, starting at 8 June 2016 00 UTC. Various vertical integral operators are used in hydrostatic approximation. Top: CERAD – Central European Radar information. Middle left: finite differences; middle right: cubic VFE of ECMWF; bottom left: new cubic VFE; bottom right: new 7$^{th}$ order VFE.*




It appears persistently in averages, not only occasionally. This is in contradiction with the previous ECMWF conclusions and it needs further investigation.

**The topic is ONGOING.**

**Contributors:** Jozef Vivoda (SHMI), Petra Smolíková (CHMI)

**Executed efforts:** 3 PM of local work

*Figure 2: The dynamic tendency of enthalpy cumulated in 12 hours; solutions for various VFE integrals are overlapping.*

**Documentation:**

- Jozef Vivoda, Petra Smolíková, Juan Simarro, *Finite elements used in the vertical discretization of the fully compressible core of the ALADIN system*, Mon. Wea. Rev. 146 (10), doi:10.1175/MWR-D-18-0043.1
- Jozef Vivoda, *Testing NH VFE integral operator in HY model core and further development of new vertical divergence variables*, report from the stay, 2018

## 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 tuneable parameters and includes not only flow dependent grid-point diffusion, but a supporting spectral diffusion as well. The behaviour 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 was redesigned. Two domains were prepared for clean tests covering roughly the same territory and differing in the resolution. We will continue the work.

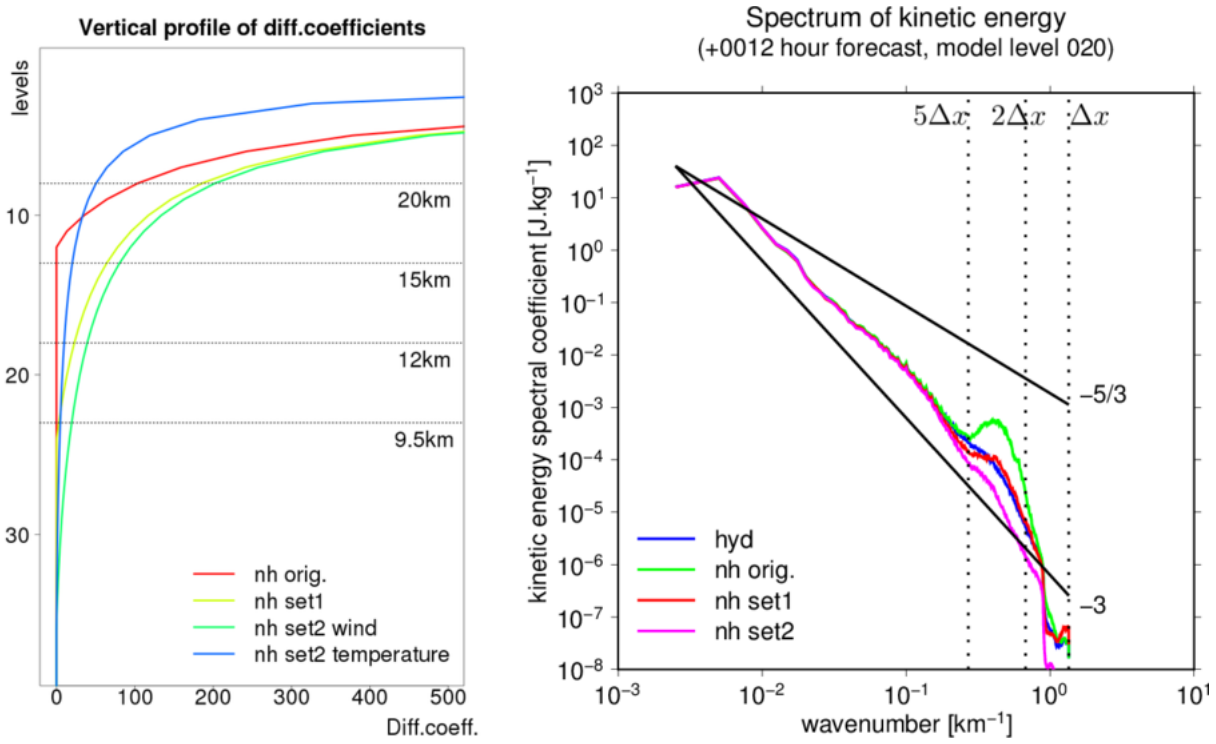



*Figure 3: Setting dynamic parameters for the new Czech operational application. Left: Vertical profile of the diffusion coefficient for reduced spectral diffusion; in the new setting the coefficient for temperature is more reduced (blue line), the coefficient for vorticity/divergence is set non-zero in extended part of the domain (dark green). Right: The kinetic energy spectrum at 20th model level for different runs.*

**Status:** The research stay of Viktoria Homonnai has been canceled at the beginning of 2018 for her nonavailability through an engagement in other tasks. Several high resolution tests have been prepared in frame of the preparation work of the next operational suite of CHMI at 2.325km. It was shown that the current horizontal diffusion setting may not be used in the higher resolution and new setting with spectral diffusion applied in thicker layer close to the domain top was proposed. The proposed setting has been tested on two series of

experiments (summer and winter). Several characteristics were calculated as objective scores, kinetic energy spectra, temperature spectra and DDH diagnostics. Some of the results achieved are presented here for an illustration. The proposed setting of dynamical parameters has become a baseline for the new operational application of ALARO at the 2.325km horizontal resolution being run at CHMI since 5 March 2019.

More general self adapting tuning of the horizontal diffusion is envisaged for future work.

**The topic is ONGOING.**

**Contributors:** Radmila Brožková (CHMI), Petra Smolíková (CHMI)

**Executed efforts:** 3 PM of local work

**Documentation:**

- Petra Smolíková, *Dynamical parameters for the new operational application of the ALADIN System at CHMI aiming to use nonhydrostatic equations at 2.325km horizontal resolution*, report on the LACE web pages , 2019 (18pp)

## Task 3. Time scheme

**Subject: 3.1 Generalization of the semi-implicit reference state to include vertical profile of background variables and horizontal features as orography**

**Description and objectives:** One of the possible ways to attack this subject is a direct inclusion of the tangent-linear approximated model in the semi-implicit time scheme. The stabilising effect of such method 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 vertical 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 this new design of SI scheme would be no need of the spectral space representation of model variables and of transformations between spectral and grid-point spaces 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). There are other less ambitious ways how the vertical profile of the reference state could be incorporated in the semi-implicit scheme which may be also investigated.

**Status:** **The topic is PENDING.**

**Executed efforts:** none

**Documentation:** none

**Subject: 3.2 The trajectory search in the SL advection scheme**

**Description and objectives:** It was reported that LPC_FULL scheme with reiteration of SL trajectories produces noisy solution. We have confirmed these results. We tried to understand this phenomenon. As we increase the model horizontal resolution, the local divergence can increase significantly and the Lipschitz criteria may be broken locally. Then the trajectory search may become divergent and 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. First test were started in 2017 which did not reveal any serious problem with the convergence. The prepared environment will be used for systematic testing on longer period.

**Status:** The horizontal and vertical Lipschitz numbers were calculated based on the maximum norm as in Diamantakis (2016). A code adaptation was needed for this goal. Then these numbers were compared with several proposed diagnostic numbers evaluating the convergence/divergence of the iterative algorithm for the semi-Lagrangian trajectory search. It was shown that there is a nice correspondence between them in the horizontal direction (seen on horizontal and vertical cross sections, and histograms) while in vertical the Lipschitz number represents only some upper limit for the convergence diagnostic. See Fig.4 for an illustration of results obtained. The algorithm was applied based on these characteristics enabling to use exactly as many iterations as needed for each grid point. If the iterative process is found to be divergent in a given grid point, the calculation is stopped. If the iterative process is found to give close results in two consecutive iterations, the calculation is stopped as well. We compared results of this method with the reference ones in longer time series (7 days, integration once per day for 72 hours) and found no significant effect. We conclude the following:

1) At least 4 iterations are needed for correct behavior of the algorithm. The price to be paid in CPU time is small (< 0.1%). Objective scores for a two weeks time series may be seen in Fig.5.

2) No benefit of the algorithm restricting the number of iterations can be seen on objective scores.

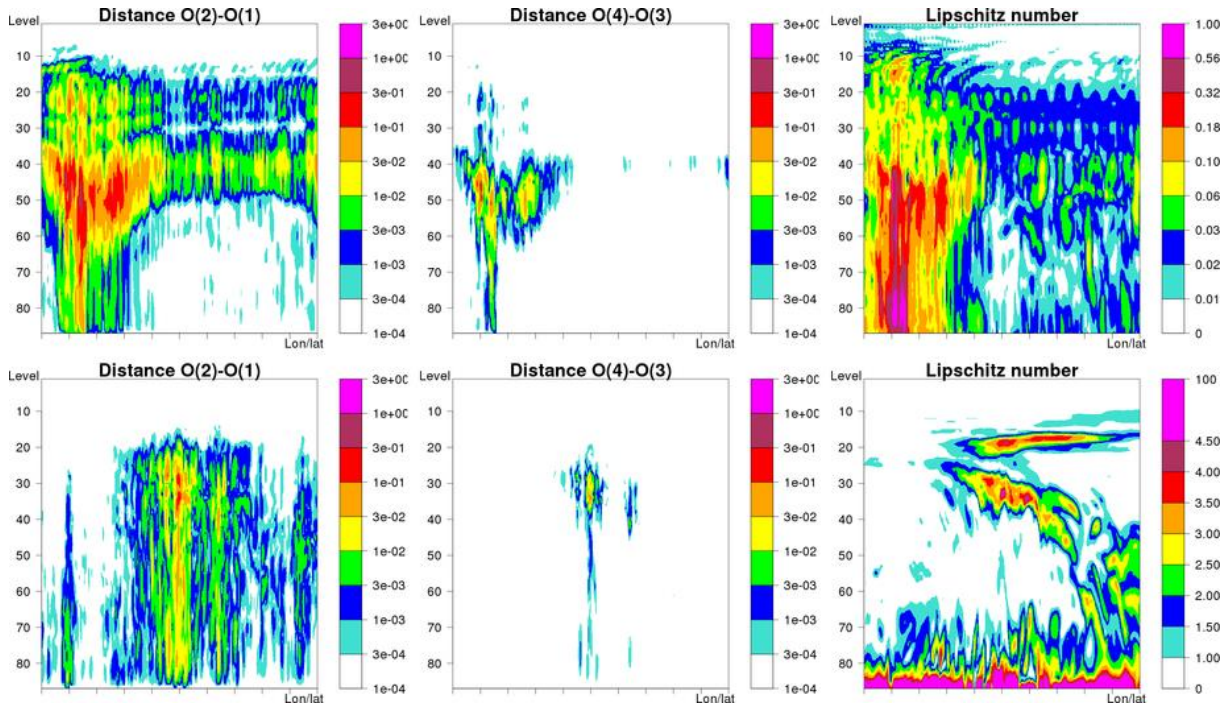



*Figure 4: Several diagnostics of convergence of the trajectory search algorithm – vertical cross section over the Alpine region. From left to right: distance of origin points from the first and second iteration; distance of the origin points from the third and fourth iteration; Lipschitz number. Top: in horizontal; bottom: in vertical.*

[M.Diamantakis and L.Magnusson, *Sensitivity of the ECMWF model to semi-Lagrangian departure point iterations*, doi:10.1175/MWR-D-15-0432.1]

**The topic is ONGOING.**

**Contributors:** Alexandra Craciun (Meteo Romania), Petra Smolíková (CHMI)

**Executed efforts:** 1 PM research stay at CHMI (Alexandra Craciun), 2 PM of local work

**Documentation:** The detailed report may be found on the LACE web pages

- Petra Smolíková and Alexandra Craciun, *Semi-Lagrangian trajectory search in the ALADIN System*, 2019 (8pp)

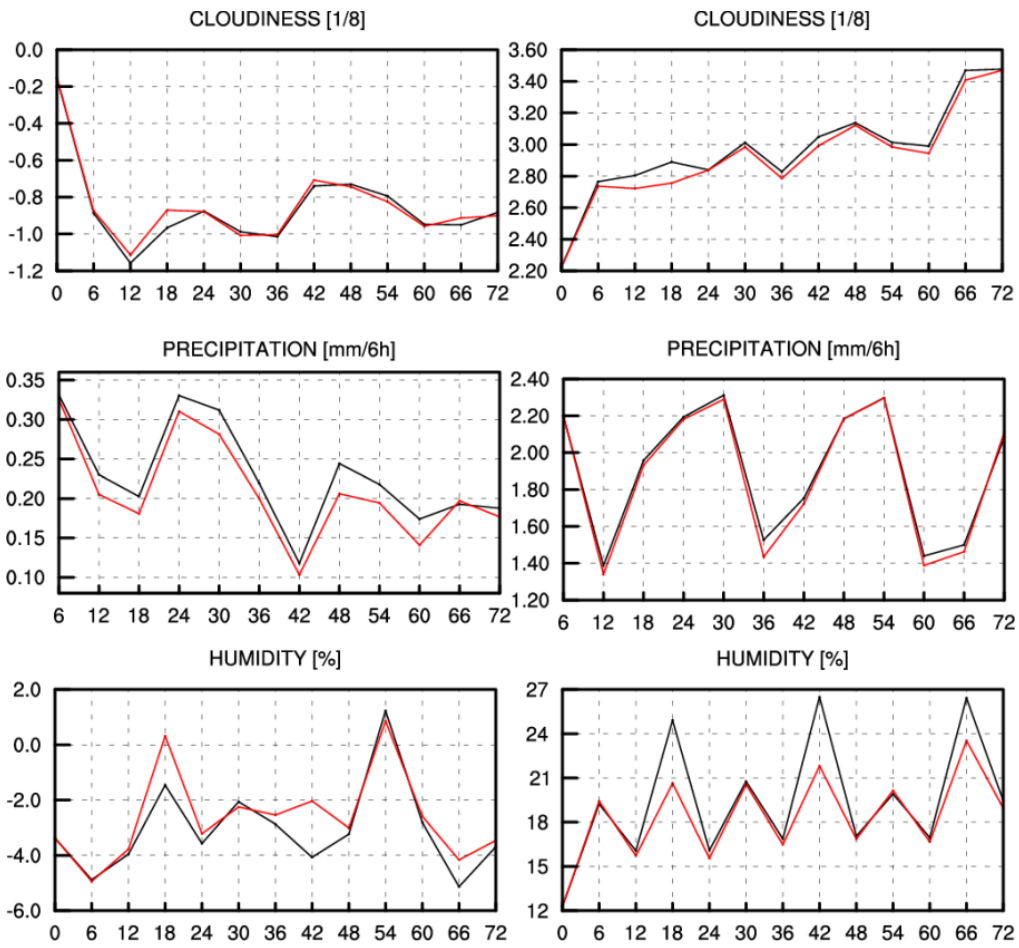



*Figure 5: Comparison of the objective scores for an integration with 4 iterations in the SL trajectory search algorithm (red) and an integration with only 2 iterations (black). Left: BIAS, right: RMSE. Top: cloudiness, central: precipitation, bottom: relative humidity. Integration once per day for the first half of January 2017. Central European domain with 1km horizontal resolution.*

### Subject: 3.3 Dynamic definition of the iterative time scheme

**Description and objectives:** Tests in higher horizontal resolutions then those used currently in operational applications (being close or less than 1km) reveal that in most of the cases the SETTLS time scheme is enough to deliver stable solution while there appear some cases when at least one iteration of the iterative centred implicit scheme is needed. When going to higher resolutions it may happen that even one additional iteration (corrector) is not enough as reported by Karim Yessad. The idea of this topic is to determine a condition which will evaluate the stability of the integration and in case there is an indication of poor stability the

iteration will be started. Ones such condition defined, the time scheme would become more efficient and the computer time will be invested only when needed. Iterative time stepping procedure could be used as well regularly every Nth time step (N>1) to better balance the cost/stability properties of the whole scheme. Implementation of such choice would require careful allocation of corresponding buffers and thorough handling of the data flow between consequent time steps treated in a different way.

**Status:** The proposed scheme was implemented in the code on the base of CY43 and tested in a simplified context in 2017. The usage of SETTLS was harmonized with the key LPC_CHEAP of the PC scheme. The final combined scheme may use either NESC or SETTLS extrapolation for the non-linear residual in the predictor step of the PC scheme depending on a stability measure, and then the global information about the usage of SETTLS/NESC scheme is calculated for each prognostic variable and each vertical level and gathered together to indicate the number of consecutive corrector steps needed for a stable integration. The modification prepared in 2017 is being phased to cycle CY46T1.

**The topic is ONGOING.**

**Contributors:** Jozef Vivoda (SHMI), Petra Smolíková (CHMI)

**Executed efforts:** 0.5 month of local work

**Documentation:** Short comment to the prepared branch of CY46T1.

### Subject: 3.4 Terms redistribution through new vertical motion variables

**Description and objectives:** Motivated by the work of Fabrice Voitus being presented at the ALADIN Workshop in Toulouse in April 2018 we started this new subject. The aim is to reformulate the nonhydrostatic nonlinear model to obtain simple bottom boundary condition which is easily fulfilled. This aim may be reached only for restricted choices done in the dynamics of the ALADIN system. In particular, only the case when vertical velocity variable is used in the nonlinear nonhydrostatic model in the two-time level SI SL scheme. The bottom boundary condition was proven to be very important for the stability and accuracy of the whole discretization of the system of prognostic equations.

**Status:** Several definitions of the vertical motion variable were proposed (w5, w6, w7) with consequencies on the prognostic equations system and on the time-space discretization of this system. Stability analysis was prepared for a simplified prototype of the proposed evolution equation showing the most promising tracks. Simplified academic tests (the potential flow) were prepared confirming and extending the conclusions made. It was found

that the stability of the system may be enhanced if the newly proposed vertical velocity is relaxed towards simple w near the model top. A smooth relaxation function was introduced

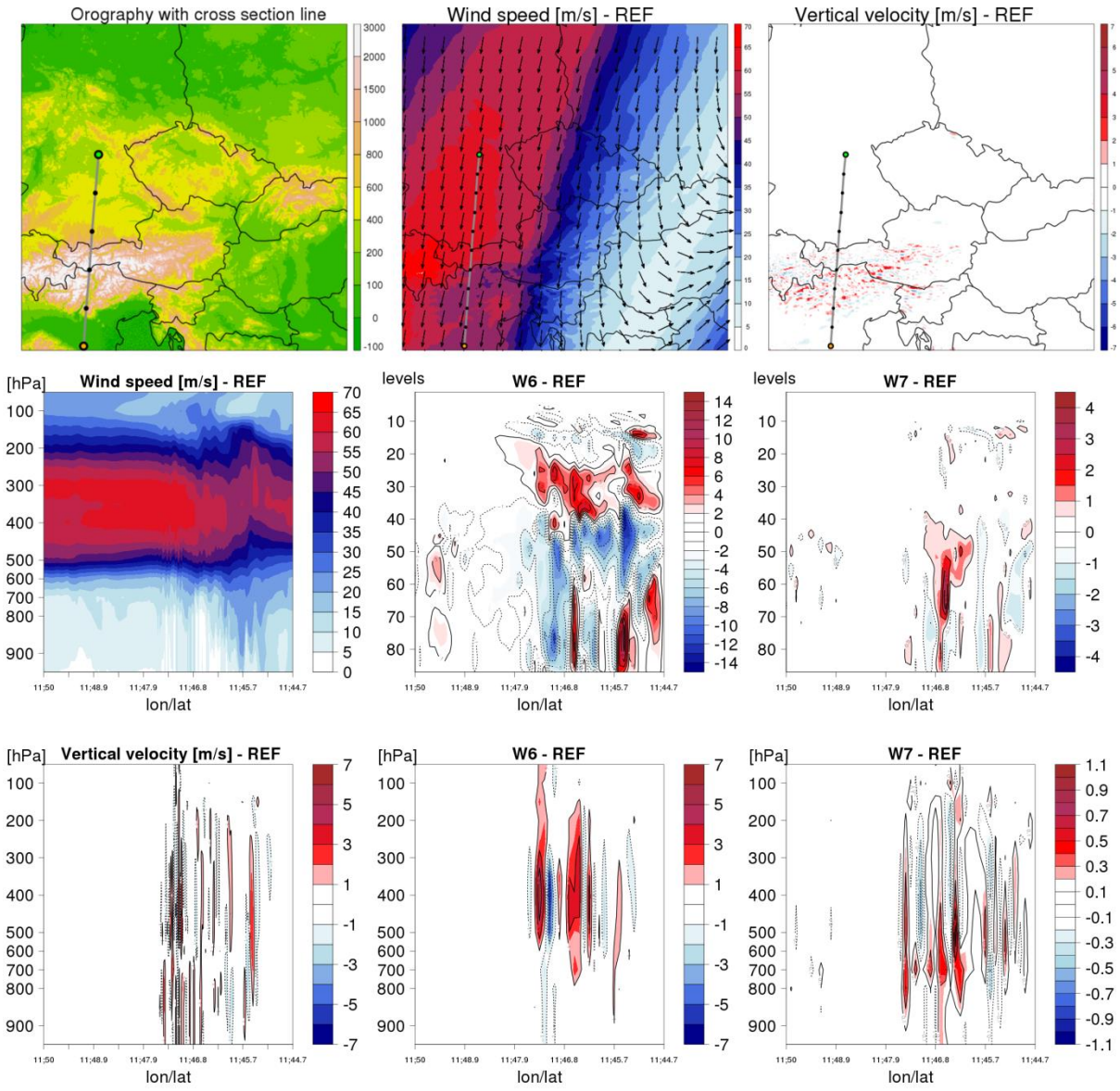



*Figure 6: New definitions of vertical velocity in a NH simulation. Top: left - orography with the vertical cross section line; middle - horizontal wind speed at 300hPa; right: vertical velocity at 300hPa. Central: Vertical cross section through the horizontal wind speed array (left: reference; middle: the difference w6expl-ref; right: the difference w7expl-ref). Bottom: Vertical cross section through the vertical velocity array (left: reference; middle: the difference w6expl-ref; right: the difference w7expl-ref).*

for this goal. The non-linear tendencies are partially treated explicitly (for w6, w7) and partially in the semi-Lagrangian manner. Depending on this treatment and w definition, we have finally 5 new different propositions for vertical velocity variable on top of the previous reference treatment. Then full 3D simulations were run to validate the analysis and academic tests conclusions in the real context. It was shown that not all the conclusions may be extended to the real world and some of them were reevaluated. We conclude that we may get substantially different results with different w solutions but a systematic validation is left for further investigation. We demonstrate the results in Fig.6. The newly proposed variables for vertical motion have been implemented in the CY46 of the ALADIN/HIRLAM system and are expected to be phased to official cycle after coordination with Météo France team.

**The topic is ONGOING.**

**Contributors:** Jozef Vivoda (SHMU)

**Executed efforts:** 2 PM – research stay at CHMI (Jozef Vivoda), 2 PM of local work

**Documentation:** Two detailed reports may be found on the LACE web pages

- Jozef Vivoda, *New vertical motion variables in the non-hydrostatic dynamical core of the ALADIN system*, 2018 (5pp)
- Jozef Vivoda, *Testing NH VFE integral operator in HY model core and further development of new vertical divergence variables*, 2018 (6pp)

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

### Subject: 4.1 Tuning of dynamical adaptation of the wind field at different resolutions

**Description and objectives:** The quality of the wind field forecast may be improved in case of strong wind and rugged terrain through a dynamical adaptation to high resolution topography by running short range forecast of the ALADIN system in higher than standard operational resolution. Wind field from the dynamical adaptation may be used as well to evaluate local wind climatology. This strategy was applied on Croatian domain to better capture the local wind “bura” being developed due to large gradients of pressure over the coastal mountains having large spatial variability and local terrain dependence. The influence of non-hydrostatic dynamics setting in several high resolution experiments (500m, 250m) will be studied.

The work is connected to physics, since the influence of parameters of the turbulence scheme is being questioned as well.

**Status:** Very high resolution (500m, 250m) experiments were run as the dynamical adaptation of the wind field using high resolution topography. The domain covers the Adriatic Sea and the Croatian coast. Only hydrostatic dynamics and pTKE scheme for turbulence parametrization were employed so far. Constant LBC's from a low resolution run of ALARO (8km) were used. The conclusions are that such experiments are technically feasible. Future strategy will be to find an optimal and stable set up for the non-hydrostatic dynamics and for more advanced turbulence scheme TOUCANS, and possibly to abandon the strategy of constant LBC files.

**The topic is ONGOING.**

**Contributors:** Martina Tudor

**Executed efforts:** 2 pm of local work

**Documentation:** The report may be found on the LACE web pages

- Martina Tudor and Stjepan Ivatek-Šahdan, *Report on very high resolution experiments* (5pp)

**Subject: 4.2 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 is difficult to be implemented. 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.

**Status:** **The topic is PENDING.**

**Executed efforts:** none

**Documentation:** none

## Task 5. Optimization of the model code to better balance computer resources/results achieved

**Subject:** **5.1 Single precision**

**Description and objectives:** We propose to investigate the impact of limiting the precision of real-number variables used in the model code to only 32 bits (single precision) in most of the calculations instead of commonly used 64 bits (double precision). The results from annual integration of IFS and from medium range ensemble forecasts indicate no noticeable reduction in accuracy and an average gain in computational efficiency by approximatively 40%. We would like to carefully check the limited area model dedicated part of the code to obtain similar results in CPU reduction while keeping reasonable accuracy level. The envisaged code changes would be rather technical including replacement of hard coded thresholds with intrinsic precision functions, avoiding divisions by floating point numbers that may become zero etc.

**Status:** The AROME model configuration CY43T2 was compiled and run in single precision. The results comparison to double precision run is not very optimistic in contrast to the results presented by Philippe Marginaud (MF). Hence, more tests have to be done to find possible problems. Further, ALARO model configuration has to be prepared for single precision.

**The topic is ONGOING.**

**Contributors:** Oldřich Španiel (Sk)

**Executed efforts:** 0.5 PM of local work

**Documentation:** none

## Task 6. Coupling strategies

**Subject:** **6.1 Coupling files preparation from IFS global files**

**Description and objectives:** LBC files provided from IFS global files for the Croatian operational domain have worse objective scores then LBC files provided from ARPEGE files,

for some variables and some time periods. There were several possible explanations given connected to interpolation from ECMWF model grid to lower horizontal and vertical resolution (15.4km, 60 levels) to reduce the amount of transferred data, or alternatively connected to projection of ECMWF octahedral grid to the LAM Cartesian grid. Several chains may be tested to create coupling files from original IFS data (from MARS archive) and the quality of coupling files may be assessed depending on many parameters as horizontal and vertical resolution, truncation of spectral fields etc.

**Status:** The process of creating coupling files (ALADIN Lambert projection) from the IFS octahedral grid files may be accomplished with configuration 903 (post processing). This process was tested with surface scheme ISBA with the conclusion that it works well and the first results are promising, but more testing is needed to find the optimum for operational work. It also requires correspondence with ECMWF and all LACE LBC users to do the operational change.

**The topic is ONGOING.**

**Contributors:** Martina Tudor (Cr)

**Executed efforts:** 1 pm of local work

**Deliverables:** proposal for the correct process

**Subject: 6.2 Capturing rapidly moving meteorological features from LBC files**

**Description and objectives:** High resolution features entering rapidly the LAM domain may remain unidentified in LBC files. Several strategies will be studied helping to capture such features as more frequent coupling files update (1 hour), alternative temporal interpolation schemes for LBC files or usage of LBC files from the whole ensemble system. Connected problems in the assimilation cycle will be studied as well.

**Status:** Several coupling strategies were tested, among them: the mathematical formulation of the relaxation and periodization process including the windowing method (Boyd scheme), spectral blending, surface pressure tendency coupling; the coupling frequency (every time step as the reference, 1hour, 3hours); and the temporal interpolation of the LBC files (linear, quadratic, cubic). The nested model is the ALARO configuration, while the guest model is ARPEGE whose results are adapted to minimize the errors arising from different model formulations of the nested and guest models. The results were compared on the case of a small cyclone travelling across the nested domain boundary. Main conclusions may be summarized in four points:

1) Higher coupling frequency is beneficial for rapidly moving features. It is as well expensive in transfer and storage of the LBC data, of course.

2) Different temporal interpolation schemes give similar results.

3) Coupling of the surface pressure tendency may have detrimental effect on results.

4) Spectral blending is very sensitive to the length of the coupling interval and may produce large errors. Especially, it may not be combined with Boyd's method.

Further details may be found in the doctoral thesis of Martina Tudor: *Improvements in the operational forecast of detrimental weather conditions in the numerical limited area model ALADIN*, Zagreb, 2018.

**The topic is FINISHED.**

**Contributors:** Martina Tudor (Cr)

**Executed efforts:** 1 pm of local work

**Documentation:** The report is published on the LACE web pages.

- Martina Tudor, *Testing GP and spectral coupling* (20pp)

## 2. Documents and publications

Several reports already are or will be soon published on the RC LACE web pages:

1) Jozef Vivoda, *New vertical motion variables in the non-hydrostatic dynamical core of the ALADIN system*

2) Jozef Vivoda, *Testing NH VFE integral operator in HY model core and further development of new vertical divergence variables*

3) Petra Smolíková, *Dynamical parameters for the new operational application of the ALADIN System at CHMI aiming to use nonhydrostatic equations at 2.325km horizontal resolution*

*4)* Petra Smolíková and Alexandra Craciun, *Semi-Lagrangian trajectory search in the ALADIN System*

5) Martina Tudor, *Testing GP and spectral coupling*

6) Martina Tudor and Stjepan Ivatek-Šahdan, *Report on very high resolution experiments*

Publications:

- Jozef Vivoda, Petra Smolíková, Juan Simarro, *Finite elements used in the vertical discretization of the fully compressible core of the ALADIN system*, Mon. Wea. Rev. 146 (10), doi:10.1175/MWR-D-18-0043.1

## Activities of management, coordination and communication

1) **Joint 28th ALADIN Workshop & HIRLAM All Staff Meeting 2018**, 16-20 April 2018, Toulouse, France – presentation of Petra Smolíková "Dynamics in LACE"
2) **EWGLAM Meeting**, 1-4 October 2018, Salcburg, Austria – presentation of Petra Smolíková "Recent developments in LACE: new variable for vertical motion in nonhydrostatic dynamics of the ALADIN/HIRLAM system"

## LACE supported stays in 2018

1) Jozef Vivoda (Sk) - New vertical motion variables for NH dynamics (18.6.2018 - 15.7.2018 at CHMI)
2) Alexandra Craciun (Ro) - The trajectory search in the SL advection scheme (8.10.2018 - 4.11.2018)
3) Jozef Vivoda (Sk) - New vertical motion variables for NH dynamics (19.11.2018 - 15.12.2018 at CHMI)

## Summary of resources/means

The effort invested into the area of Dynamics&Coupling in frame of LACE in 2018 is 19 PM. It represents roughly 80% of planned work. There was a shift in the topic of one research stay towards a new idea presented at the ALADIN Workshop in April 2018 (New vertical motion variables for NH dynamics). We had 3 PM of research stays together, one research stay was cancelled.

| Task | Subject | | Resources | | |
|---|---|---|---|---|---|
| | | | Planned | Executed | Stays |
| 1. VFE NH | 1.1 | Design of VFE in NH model | 3 | 3 | 0 |

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|---|---|---|---|---|---|
| 2. Horizontal diffusion | 2.1 | Tuning and redesign of the horizontal diffusion depending on the scale | 3 | 3 | 1/0 |
| 3. Time scheme | 3.1 | Generalization of the semi-implicit reference state | 2 | 0 | - |
| | 3.2 | The trajectory search in the SL advection scheme | 4 | 4 | 1/1 |
| | 3.3 | Dynamic definition of the iterative time schemes | 4 | 0.5 | 2/0 |
| | 3.4 | Terms redistribution through new vertical motion variables | 0 | 4 | 0/2 |
| 4. Evaluation of the dynamical core in very high resolutions | 4.1 | Tuning of dynamical adaptation of the wind field at different resolutions | 2 | 2 | - |
| | 4.2 | Upper boundary condition | 2 | 0 | - |
| 5. Optimization of the model | 5.1 | Single precision | 2 | 0.5 | - |
| 6. Coupling strategies | 6.1 | Coupling files preparation from IFS global files | 1 | 1 | - |
| | 6.2 | Capturing rapidly moving meteorological features from LBC files | 1 | 1 | - |
| **Total manpower** | | | **24** | **19** | **4/3** |

## Problems and opportunities

**We have started interesting and promising topics and expect to be able to do valuable work in case the dedicated workforce will be available. Several topics are appropriate for a newcomer or a candidate with only limited experiences with the code of the model.**