Working Area Dynamics & Coupling

Progress Report

Prepared by:	Area Leader Petra Smolíková
Period:	January – August 2023
Date:	8/9/2023

Progress summary

This report summarizes the work done in the Area of Dynamics & Coupling of the RC LACE from January to August 2023. Two research stays were executed in this period. A valuable work was done locally as well. The work done was registered in the work packages DY1, COM3, HR, PH8 and MQA3 of the ACCORD registered workforce summary for the first six months of 2023 and partially also in the project DE_330.

We keep track of closed topics and subjects in the numbering and number the new topics and subjects with consecutive numbers. The closed topics and subjects are not listed any more in the report and thus the numbering may jump up several numbers.

1. Scientific and technical main activities and achievements

Task 1. Vertical discretization

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). The compatibility of the newly proposed vertical velocity variable with VFE will be studied and code will be modified to allow the usage of both.

Status: The blended NH/HY dynamics developed under Subject 6.1 was made compatible with VFE in the contribution to the future cycle CY49T1 which is currently under preparation.

Contributors: Petra Smolíková (CHMI)

Executed efforts: 0.5 PM of local work, not yet registered to ACCORD workforce summary

Documentation: GitHub branch smolikovap_CY49T0_blendNHHY description

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. The work started with the sensitivity study in the cascade of resolutions (4km, 2km, 1km). Moreover, the domain covering roughly the same territory with the horizontal resolution of 500m was prepared to complement the existing experimental environment. The original method was designed to determine the resolved TKE. We continue in the work.

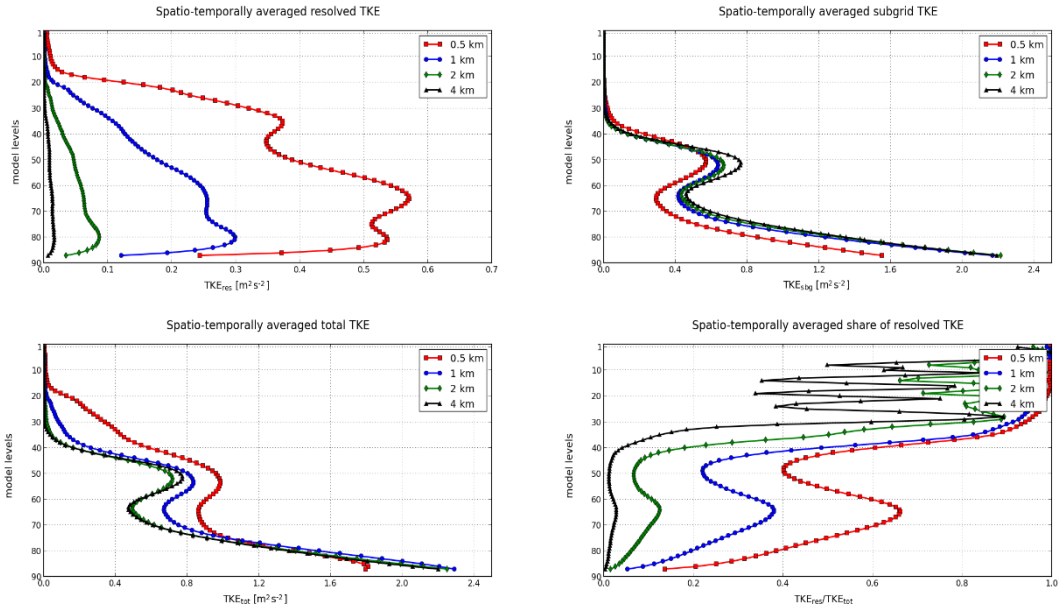

Figure 1: The resolved (top left), sub-grid (right) and total (bottom left) TKE in the cascade of resolutions. One forecast.

Status: We follow up the work previously done. The resolved and sub-grid TKE were evaluated in the cascade of resolutions (4km, 2km, and 1km). The partitioning of both above contributions was considered generally satisfying at these resolutions. However, in the middle and upper PBL, the resolved and total TKE seemed slightly overestimated at 1km.

This year we continued with even higher resolution of 500m on roughly the same experimental domain. For consistency, we kept the deep convection and gravity wave drag parameterizations. The resolved and subgrid TKE was again evaluated and it was observed that there is too much of resolved TKE in the upper PBL and free atmosphere. Further, the experiment without parameterization of deep convection (3MT) was run and it was found that the amount of resolved TKE is even increased. Then the impact of SLHD (flow dependent diffusion) was estimated with an experiment with SLHD replaced fully with the spectral diffusion. The spectral diffusion is not able to remove small scale noise correctly and it results in even increased amount of resolved TKE, mainly at the top of the domain, but in lower and higher troposphere as well, see Figure 2. The results are consistent with KE spectra analysis which also points to a considerable and unphysical increase in energy near the model top.

Perturbations of wind components (u', v' and w') are computed as differences between the predicted values and the 15-minute moving average on a subdomain of approximately 256 x 128 km. The resolved TKE is then obtained as $TKE_{res}=0.5*(u'^2+v'^2+w'^2)$ and averaged over the

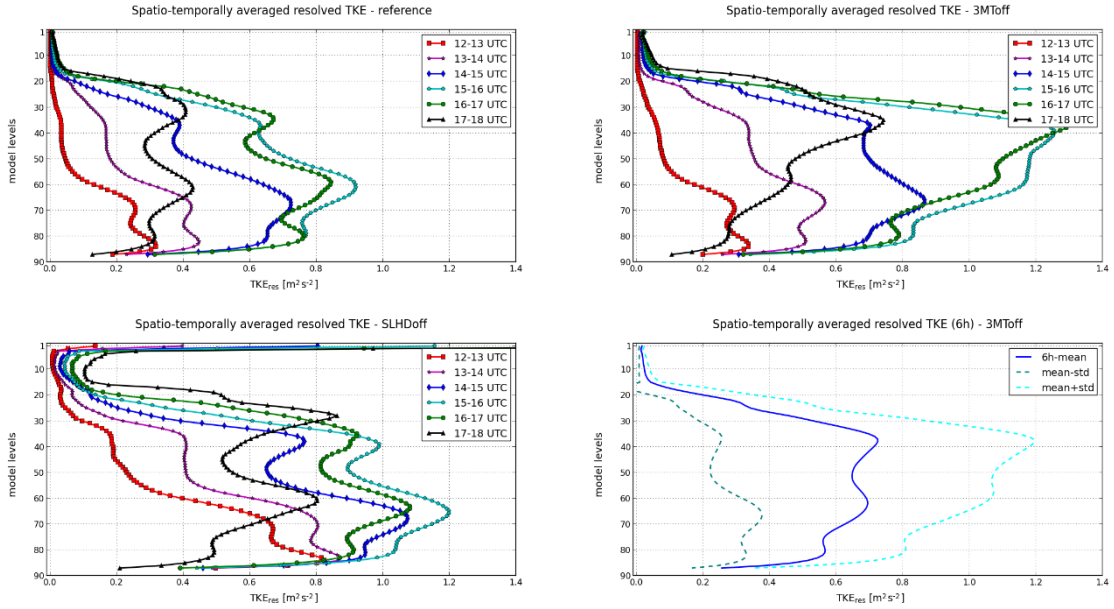

Figure 2: Temporal average of the resolved TKE for separate hour slots for the reference experiment (top left), the run without deep convection (top right) and the run without SLHD (with tuned spectral diffusion – bottom left).

entire subdomain. Finally, the values shown on plots are further averaged over 6-hours window. The method applied here is common in analysis of turbulent measurements, except for the amount of points in horizontal (typically measurements are taken at a single point or few points). In literature there are many other methods to compute both perturbations and resolved TKE and we plan to investigate the one based on so-called "coarse graining" technique. For this reason, we stored the data on the same subdomain in the cascade of above-mentioned resolutions.

We plan to assess separately the impact of supporting spectral diffusion and several parameters of SLHD. Further, we would like to see the impact of switched-off GWD parameterization. In resolutions near and under 1km, the contribution of both mentioned parameterizations, deep convection (3MT) and GWD, is supposed to be small and related processes are mostly resolved by the dynamics. In case of 3MT, it seems that there may be still a positive impact on the model variables which is to be investigated. The possibility to damp small scale noise especially close to the model top will be examined as well.

Contributors: Mario Hrastinski (DHMZ), Petra Smolíková (CHMI)

Executed efforts: 0.5 PM – research stay at CHMI, Prague; second half of the stay is planned for October 2023; 0.75 PM of local work; registered to HR and PH8 work packages of the ACCORD workforce summary

Documentation: presentation at 3D turbulence workshop, online

Task 3. Time scheme

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: A research stay of Alexandra Craciun at CHMI, Prague, is planned for November 2023.

Executed efforts: none

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

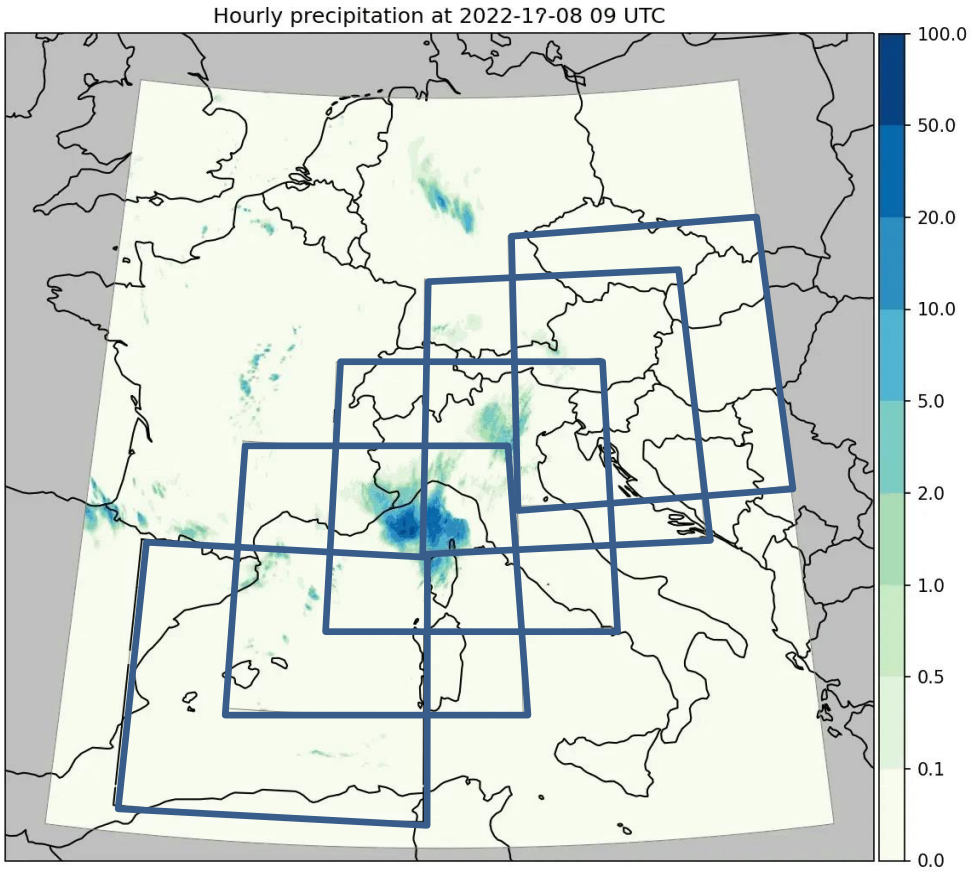

Figure 3: The precipitation calculated with AROME in the consecutive domain approach, run @Geosphere Austria.

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: The topic is PENDING. The corresponding operational application in Croatian Met Service was stopped and no replacement is foreseen for the near future.

Subject: 4.3 Experiments in very high resolution

Description and objectives: As reported by Fabrice Voitus (Météo France) the numerical stability of the ALADIN nonhydrostatic dynamical core is endangered as soon as the horizontal resolution of 350m is approached above steep orography. To be able to test this statement and to analyse the model dynamical core behaviour we must start experiments in these very high resolutions. For these goals the climate files must be prepared from a fine database.

Status: The work was registered under the work package HR of the ACCORD work plan and in DE_330 project. Several cases were identified as difficult to be run in high resolution. These cases are being shared among several contributors.

VHR experiments @Geosphere Austria

A cascade of AROME runs (2.5km, 1.25km, 500m) was prepared at Geosphere Austria for the case of 18/08/2022 0UTC + 24h. According to the goals of the DE_330 project a so called "consecutive domain" approach was applied, i.e. run a big domain on 1.25km coupled to IFS HRES and then run AROME on several 500m domains nested inside (partly overlapping) coupled to the AROME 1.25km. Stability issues were observed for the 500m runs which could not be solved by simple namelist parameters changes. Figure 3 shows the consecutive domains and a snap shot of precipitation amounts obtained.

VHR experiments @CHMI

At CHMI, the same case in August 2022 was run over the Central Alps in the cascade of resolutions to finally get the horizontal resolution of 200m. The following configurations,

resolutions and domains were involved:

- Global application ARPEGE @ Météo France operational resolution, 105 vertical levels, linear truncation, quadratic truncation of orography
- LAM ALARO @ 2.325km, 87 vertical levels, linear truncation, quadratic truncation of orography. timestep of 90s
- LAM ALARO @ 500m, 87 vertical levels, linear truncation, quadratic truncation of orography, initialized via DFI, timestep of 20s
- LAM ALARO @ 200m, 87 vertical levels, linear truncation, cubic truncation of orography, initialized via DFI, timestep of 8s

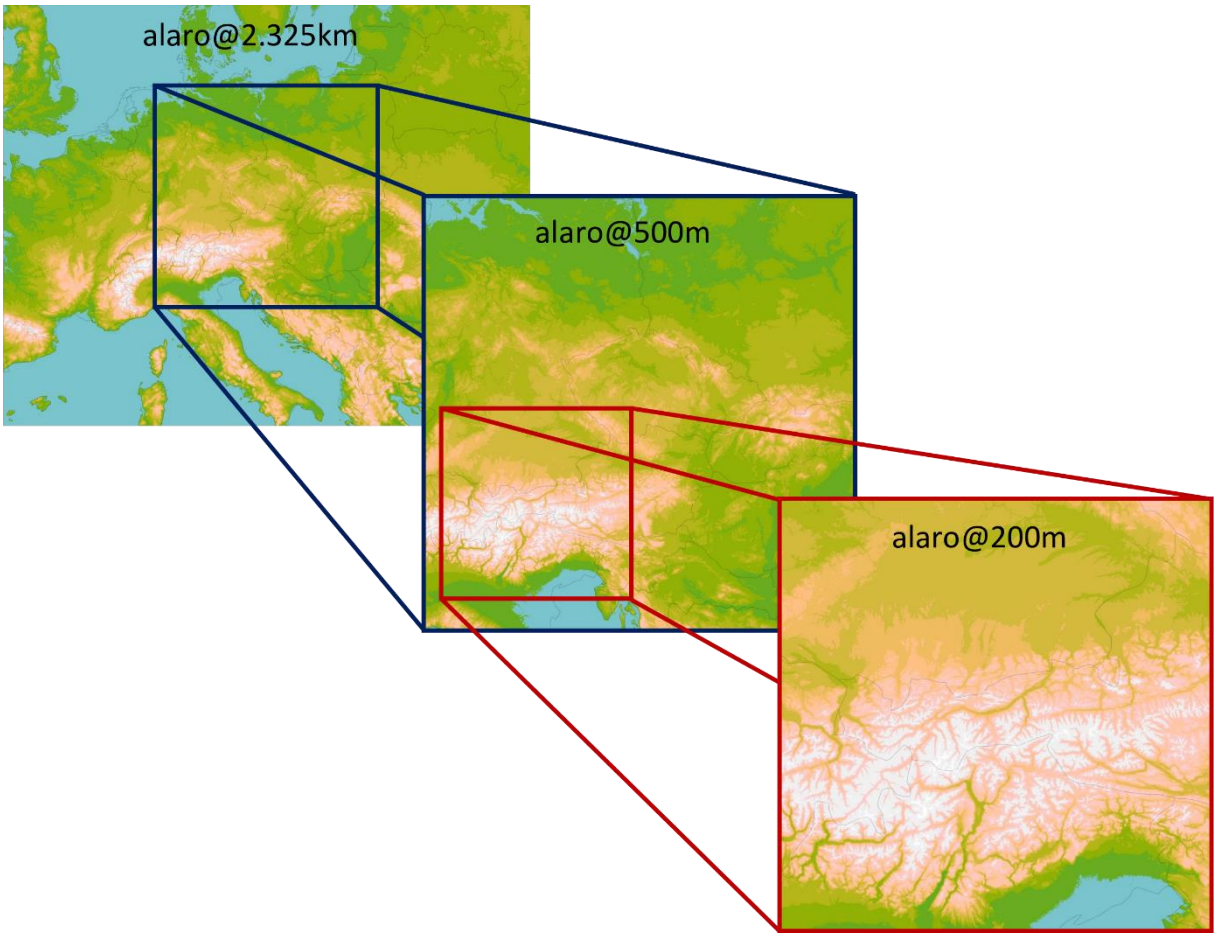

Figure 4: Domains and their orography for VHR experiments @CHMI.

Comparison of orography with cubic truncation @200m, quadratic truncation @200m, quadratic truncation @500m interpolated to 200m is shown in Figure 5 as the cross section in

parts with highest horizontal gradient of vertical divergence. All fields are after DFI initialization. All values are scaled, temperature is diminished by 273K. The initial file with orography interpolated from 500m resolution was created using NFPCLI=0 in configuration e927.

We see on Figure 5 that with quadratically truncated orography (green) @200m extremely low values of vertical divergence appear in the initial file which prevent the integration to be stable. More realistic values appear with cubic truncation of orography (blue).

The experiments at 2.325km and 500m resolutions do not suffer from any stability problems and no noise is detected in the results. We focus on the results of the 200m resolution run. The stability and accuracy of the obtained results is influenced by the filtering techniques used. Several horizontal diffusion configurations were used, either with spectral diffusion only or combined with SLHD. The second order decentering was also tested. The best results were obtained with SLHD, or with modified spectral diffusion (stronger especially for motion variables).

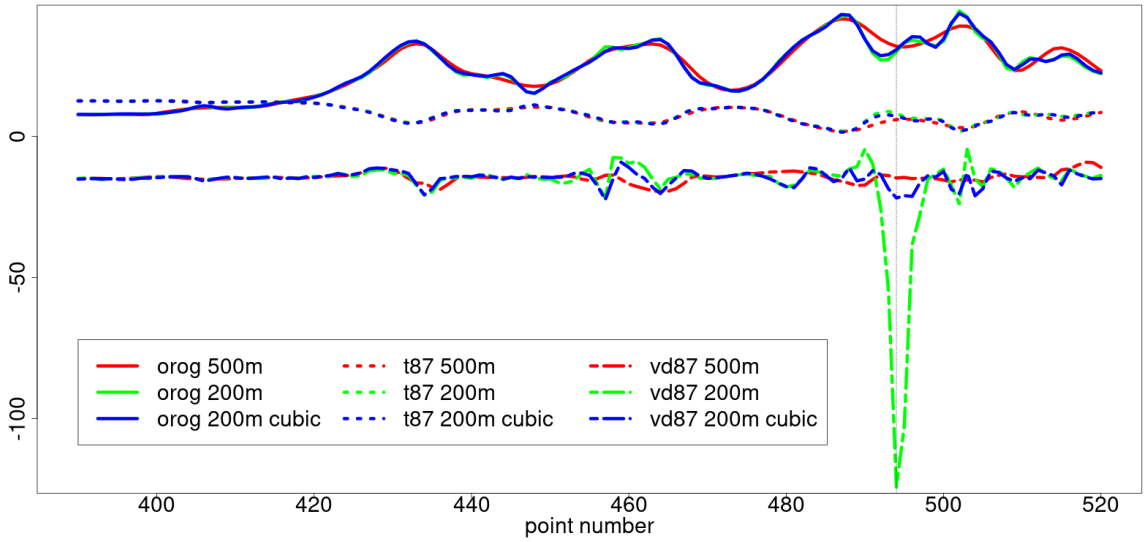

Figure 5: Orography (full line), temperature (dotted line) and vertical divergence (dot-dashed line) at the lowest model level for three initial files: with interpolated orography from 500m resolution (red), quadratically truncated orography@200m (green line) and cubicly truncated orography @200m (blue line).

We present for illustration of obtained results the time evolution of spectral norms of pressure departure, vertical divergence, temperature and kinetic energy (Figure 6) and pressure departure field at 80th model level (Figure 7). No comparison with the measurements was

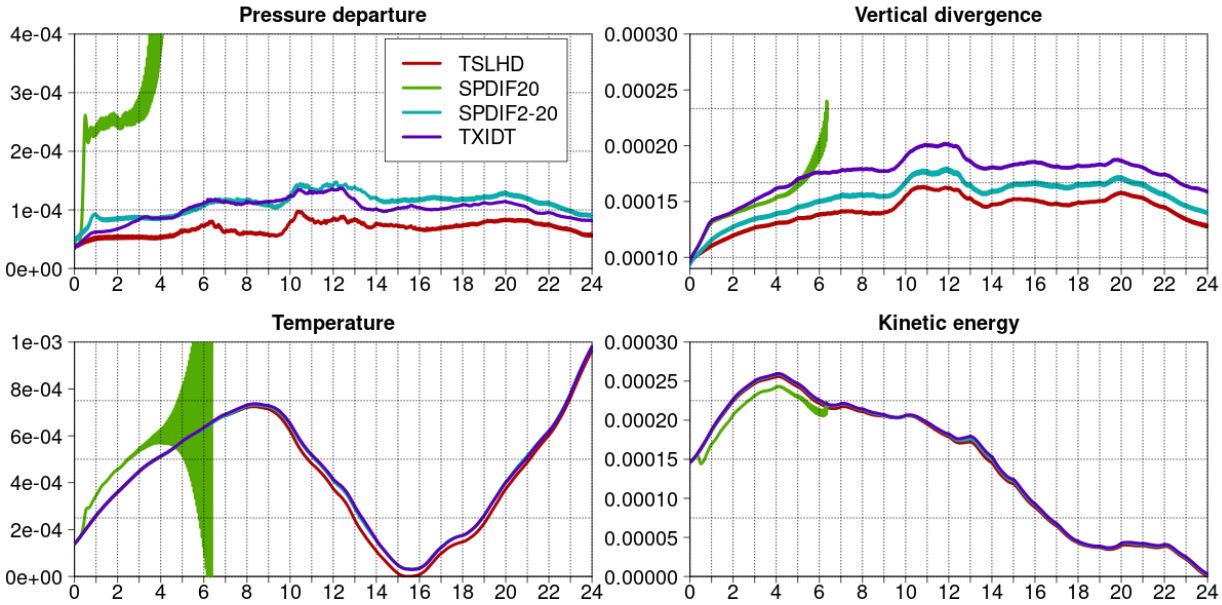

Figure 6: Evolution of spectral norms averaged over the whole domain for pressure departure, vertical divergence, temperature and kinetic energy for several experiments. All values are scaled. (TSLHD – SLHD used, SPDIF20 – standard spectral diffusion, SPDIF2-20 – spectral diffusion stronger for motion variables, TXIDT – second order decentering in the time scheme.

prepared. It is planned for future.

We may summarize the results:

1. A sharp orography will compromise the stability of the integration. Smoothing the fields in the initial file might help but handling orography spectra is more efficient. Cubic truncation of orography was used successfully with ALARO.
2. The digital filter initialization helps to bring balance to the initial fields and can avoid unstable integration at the beginning of the run at high resolutions.
3. The stability of integration depends strongly on the horizontal diffusion parameters used.
4. With spectral horizontal diffusion only, when going to higher resolution the automatic adaptation of the diffusion coefficients is not enough and more strengthening is needed. This holds particularly for motion variables (vorticity, divergence and vertical divergence). The strength of diffusion applied on temperature, pressure departure and humidity seem to play a less important role.
5. With properly set horizontal diffusion, we may get stable integration with “standard

setting" in dynamics, i.e. PC scheme with one iteration, and no special changes to other parameters except for lower value of SITRA.

6. No changes were done in the parameterization schemes of ALARO. Some tuning could be beneficial and is planned for the future.

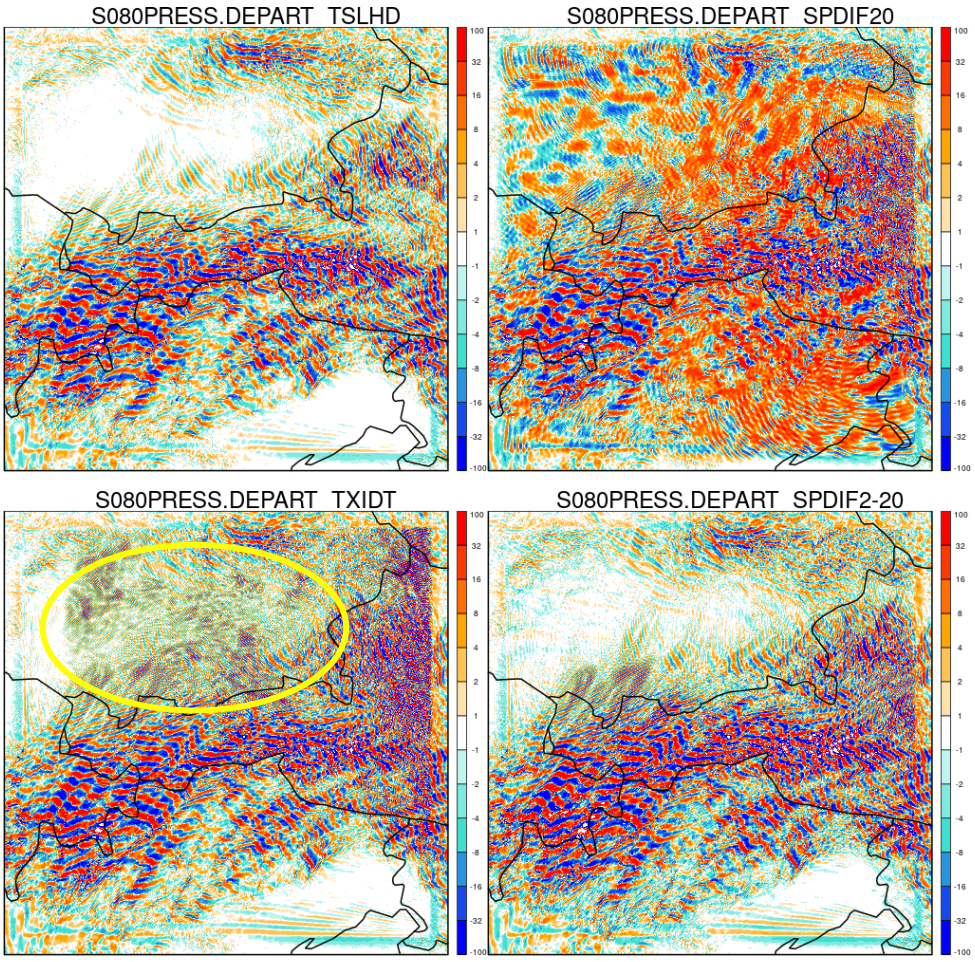

Figure 7: Pressure departure at 80th model level for several experiments, run from 18 August 2022, 00 UTC + 12 hours. The yellow circles denote the locations of small-scale noise appearing with second order decentering.

VHR experiments @SHMI

Several test cases were run in 750m resolution and in 250m resolution on domains from Figure 8. The impact of different parameters of the coupling process was evaluated. The results for the case of 16 May 2021 00 UTC +24h can be summarised as follows:

1. Large impact of used LBCs and coupling frequency (with 1h coupling frequency results were more exact).
2. Not so sensitive on the initial conditions used.
3. The use of correct, higher-resolution LBCs (from LAM model on a wider domain) was crucial to get the heavy precipitation on the right place.

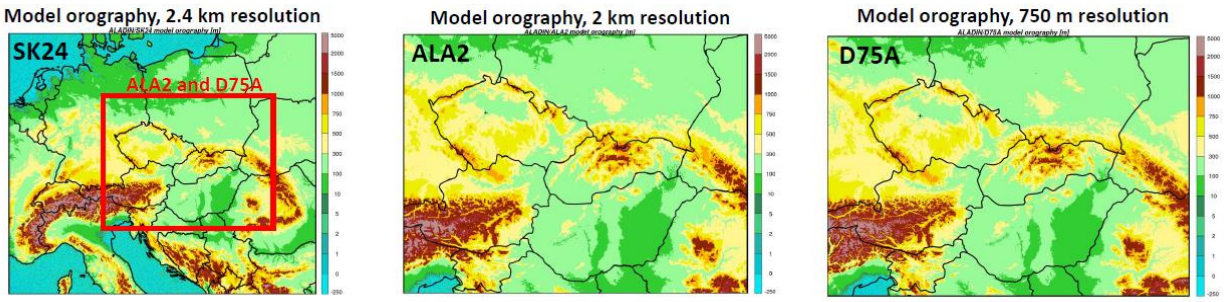

Figure 8: Model orography for domains used to produce LBCs (Left and middle) and for the final 750m resolution (right) run @SHMI.

The topic is ONGOING.

Contributors: Maria Derková (SHMI), Mario Hrastinski (DHMZ), André Simon (SHMI), Petra Smolíková (CHMI), Christoph Wittman (Geosphere Austria)

Executed efforts: 5.25 PM of local work; 4.75 from that counted for DE_330 project; registered to HR and PH8 work packages of the ACCORD workforce summary

Documentation: Some details may be found in the document "*Preliminary study on optimal forecast configuration parameters for DEODE-DT (upper-air and surface)*" prepared as the deliverable of the DE_330 project.

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-numbers 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: Standard tests with single precision run for AROME in Davai. It means that the dynamics is prepared correctly in selected configurations. We may investigate compatibility of less frequently used options in dynamics with single precision.

Status: **The topic is PENDING.**

Subject: 5.2 The FFTW algorithm

Description and objectives: It was reported by Météo France, that the usage of the Fastest Fourier Transform in the West algorithm may bring substantial CPU savings depending on the platform used (up to 5%). We will test the possibility to run this algorithm in the export code cycle CY46t1 and assess its performance compared to the standard FFT algorithm.

Status: **The topic is PENDING.**

Executed efforts: none

Task 6. Basic equations

Subject: 6.1 Reformulation of the NH system as a departure from HPE

Description and objectives: Currently hydrostatic (HY) and fully compressible nonhydrostatic (NH) system of equations and its numerical integration form two dynamical cores which are separated in a substantial part of the model code. Recently Voitus showed that unification in the spectral Helmholtz equation solver is possible through elimination of all variables except horizontal divergence in both these worlds. The aim of the topic is to reformulate the compressible nonhydrostatic system of equations as a departure from the hydrostatic system which may be controlled through several control parameters (all= 1 NH core, all = 0 HY core). Then all computations of the dynamical core can be treated in a unified code. Moreover, these control parameters can be vertically dependent. It would allow to suppress nonhydrostatism close to the model top where the vertical resolution is too coarse to properly sample NH processes.

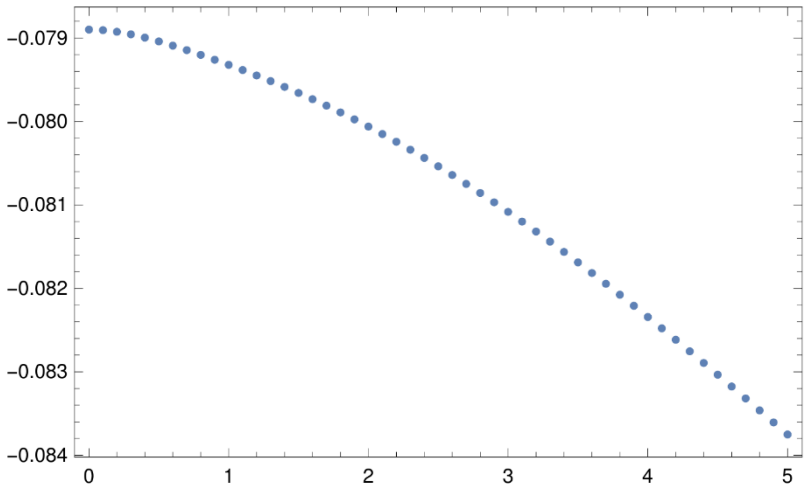

Figure 9: Maximum eigenvalue of the newly proposed vertical Laplacian depending on the slope (x-axis).

Status: The forces were driven to the publication of the obtained results in Monthly Weather Review. A paper submitted to MWR was revised and finally published. Moreover, a contribution to future cycle CY49T1 was prepared containing the mentioned approach. On top of that, we followed a proposal of Fabrice Voitus and Jozef Vivoda to include partially the orography into the linear operator of the SI time scheme. Only second order terms associated with the horizontal gradient of geopotential are preserved and the horizontal gradient of geopotential is approximated with the maximum possible surface value in the given domain multiplied with a vertically dependent function describing the geopotential change with the eta coordinate. Then, the linear model is being developed and the elimination of variables up to horizontal divergence is proposed. The procedure results in a design of a new vertical Laplacian operator which contains orography dependent terms. For stability reasons we need to obtain an operator whose eigenvalues are all real and negative. We present in Figure 9 the dependence of the maximum eigenvalue of the newly proposed vertical Laplacian on the maximum slope used. We may see that for all possible values of the slope, the maximum eigenvalue is negative and thus all eigenvalues are negative. Moreover, they are real as well. The necessary condition for stability is thus satisfied.

Then, idealized experiments in the 2D vertical slice model were prepared which showed that the stability of the time scheme may be enhanced with the proposed method. See Figure 10 for an illustration of results. Further investigation is needed.

The topic is ONGOING.

Contributors: Nika Kastelec (ARSO), Petra Smolíková (CHMI)

Executed efforts: 1 PM -research stay of Nika at CHMI, 2.5 PM of local work; 1PM from that

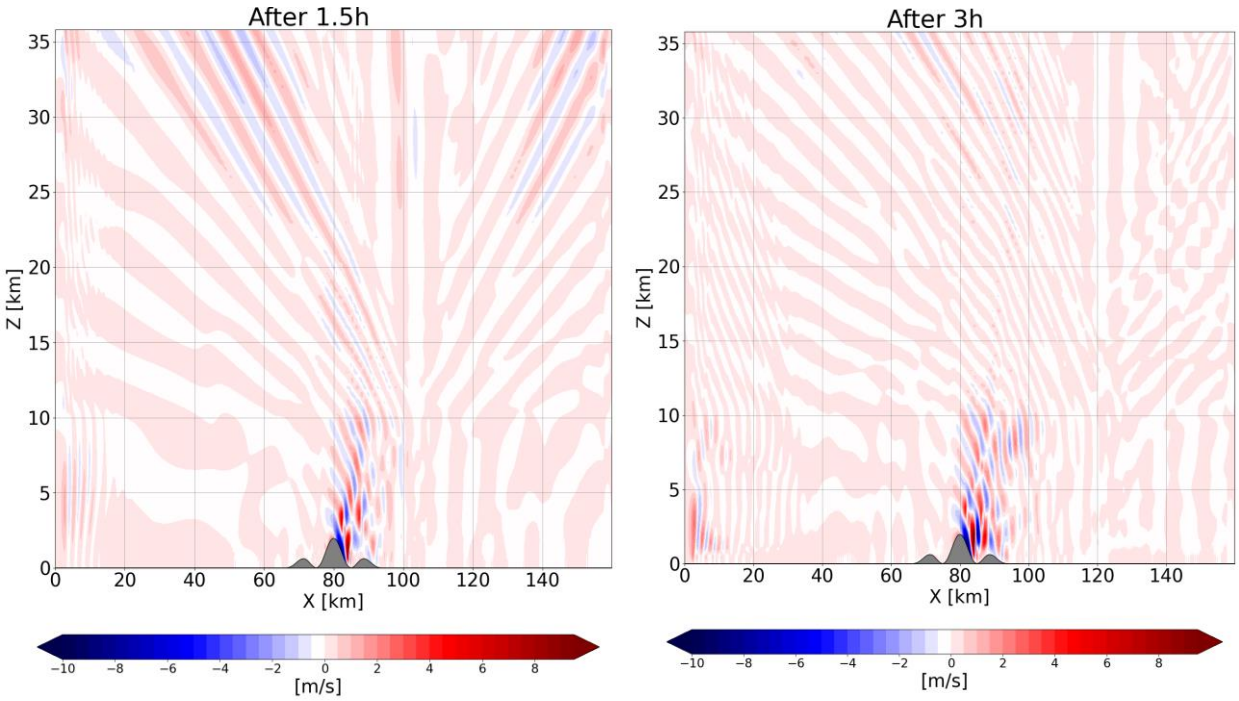

Figure 10: Vertical wind in a 2D experiment with Schär orography. Left - with slope zero used in the vertical Laplacian of the linear model after 360 steps of integration, crashed after 378 steps; right - with the slope 0.23 still stable after 720 steps of integration.

counted for DE_330 project; registered to DY1 work package of ACCORD workforce summary

Documentation: a paper published in MWR, a report from Nika's stay available on the RC LACE web pages.

Task 7. Coupling strategy

Subject: 7.1 The impact of higher coupling frequency

Description and objectives: The impact of higher coupling frequency was already investigated in the past and revealed an interesting option which may help to capture meteorological features which would be omitted with lower coupling frequency. Moreover, the LBC files started to be operationally available for the LACE domain in 1h frequency recently. We would like to assess the impact of the increased frequency of coupling on real cases in the context of our current operational resolutions. The operational usage of 1h coupling frequency is limited by the available transfer speed of LBC files to the partner countries.

Status: **The topic is PENDING.**

Subject: **7.4 Preparation of new LBC files from IFS**

Description and objectives: Preparation of new LBCs in higher horizontal and vertical resolution from the IFS files is planned for the new operations. Problems with the performance of the e903 procedure were detected and need to be solved.

Status: There were four parallel tests made, in Slovakia, Austria, Croatia and Hungary. The experiments run were based on cy48t1 and the following setting of the LBCs prepared from HighRes IFS runs:

A - 15.4 km / 60 L (file size 10 MB) – previously used operational setup

B - 8.5 km / 105 L (file size 30 MB)

C - 8.5 km / 105 L including hydrometeors qi/ql (file size 76 MB)

D - 8.5 km / 137 L (file size 36 MB)

On top of it, Austria run the control experiment with the previous model cycle

E - 15.4 km / 60 L (file size 10 MB) – previously used operational setup on cycle CY46R1.

Hydrometeors were used for coupling only, in Austrian and Croatian tests. The conclusions are in an absolute accordance and can be summarized in the following:

1) On average, there is hardly any difference visible when checking scores/results after increasing horizontal and vertical resolution of LBCs.

2) There is no difference visible when lower number of vertical levels is used, but placed in troposphere according to ECMWF, (105L) compared to the full set (137L).

3) No improvement was found for coupled hydrometeors, and the files are much bigger.

4) Significant difference is just given when comparing runs with the new LBCs to the runs using LBCs from the previous IFS OPER version. So biggest difference is coming from IFS CY46r1 vs. IFS CY48r1. The difference is declared by ECMWF to be meteorologically insignificant.

5) Although there is hardly any difference visible, the (B) 8.5km / 105L setup is being preferred, as it is still expected that in some cases higher horizontal and in particular vertical resolution should make a difference.

Austria: Figure 11 illustrates the conclusions 1,2 and 4.

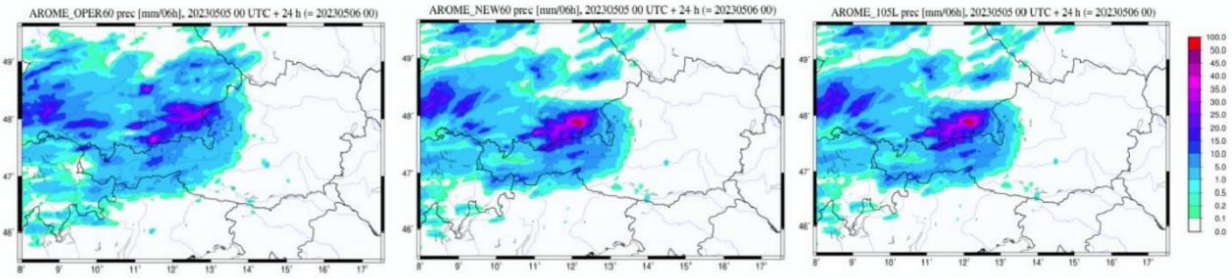

Figure 11: Precipitation on 22.5.2023 + 36 [mm/6h] for AROME Austria and run E, A and B.

Croatia: On top of dynamical adaptation, the cycled experiment with data assimilation was run. The reference experiment was initialized from the operational 3-hour assimilation cycle using previous LBCs (15km/60L) during the minimization process and coupled as well to the previous LBCs. The target experiment was prepared in a similar way but using variant B of LBCs to obtain the initial file and for coupling. Since the target experiment was run later, there is a concern about the amount of available observations compared to the reference run. Hence, the reference experiment will be repeated to ensure better comparability. The conclusion is that the bias of most upper air parameters and standard deviation for relative humidity and wind speed were improved. Improvements were observed mainly in the first 12 forecast hours. See Figure 12 for an illustration of results.

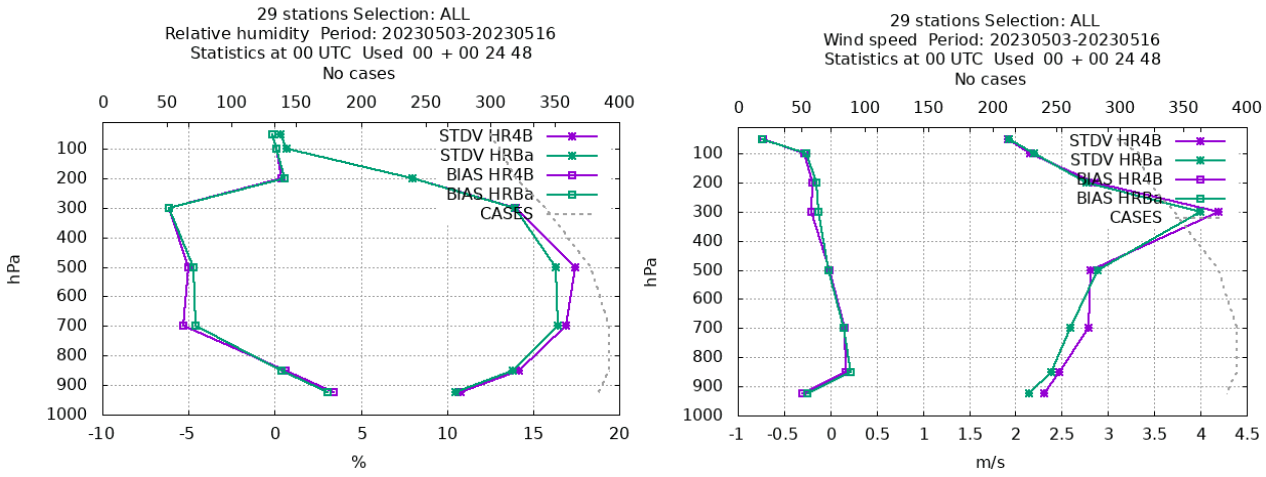

Figure 12: STD and BIAS for relative humidity and wind speed for the cycled experiment of DHMZ.

Hungary: The tests with AROME/HU were run for 4 May 2023 at 00 UTC, when a Mediterranean cyclone and a cold front affected the weather in Hungary. All the LBCs were

prepared with IFS cycle 48r1, so the meteorological content was the same along the four global forecasts, only the impact of the LBC resolution was investigated on the regional forecasts. The greatest differences were found in the fields of humidity and hydrometeors. The comparison for graupels is shown in Figure 13.

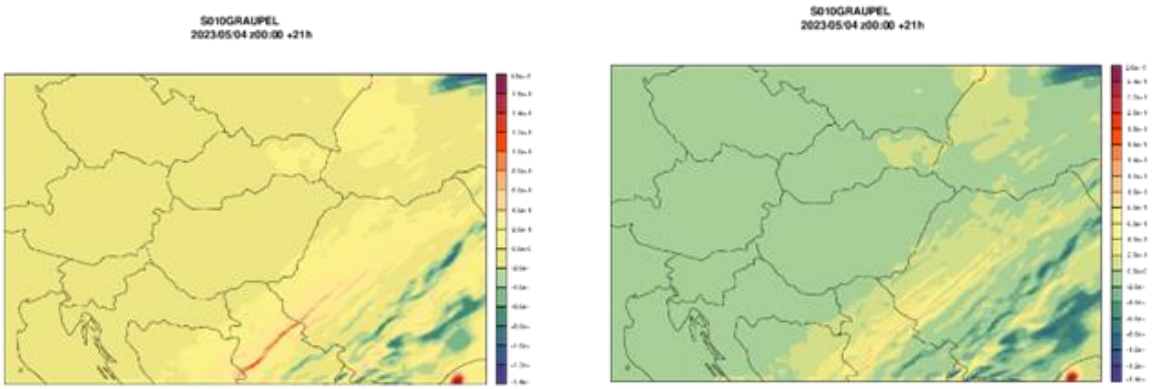

Figure 13: Differences between the AROME forecasts using the previous operational and the new LBC settings (from left to right: A-B; A-C) for graupel on the 10th model level, on 04.05.2023 00 UTC +21h.

Slovakia: Only subtle differences were observed in the precipitation forecasts coupled with the A - D variants of LBCs. Furthermore, the width of the coupling zone having 8 vs 16 points was tested. Unfortunately, none of the tests helped to improve missed convective precipitation patterns for the forecast from 3.5.2023 0UTC + 24 hours, southerly of Budapest. See Figure 14 for an illustration of results.

With such an accord in conclusions, we decided for variant B and communicated the decision to ECMWF. ECMWF has implemented setting B in the production of the LACE-LBCs in the CY48R1 esuite for HRES. Hence coupling files for RC LACE are produced on 105L without hydrometeors. The new setup became operational with the implementation of CY48R1 in June 2023.

Moreover, it was decided that for the ensemble production in RC LACE, a smaller domain than for the deterministic production is sufficient because all the ensemble applications are being run on smaller domains. There is an exception of A-LAEF which has its own suite and the LBCs are prepared separately. For C-LAEF-Austria and AROME-ENS-Hungary, we prepared a smaller domain which is shown in Figure 15. This domain is supposed to cover current and the future needs of ensemble applications of the RC LACE members. The LBCs production esuite at ECMWF creates files over this domain in 8.7 horizontal resolution with 105 vertical levels since June 2023.

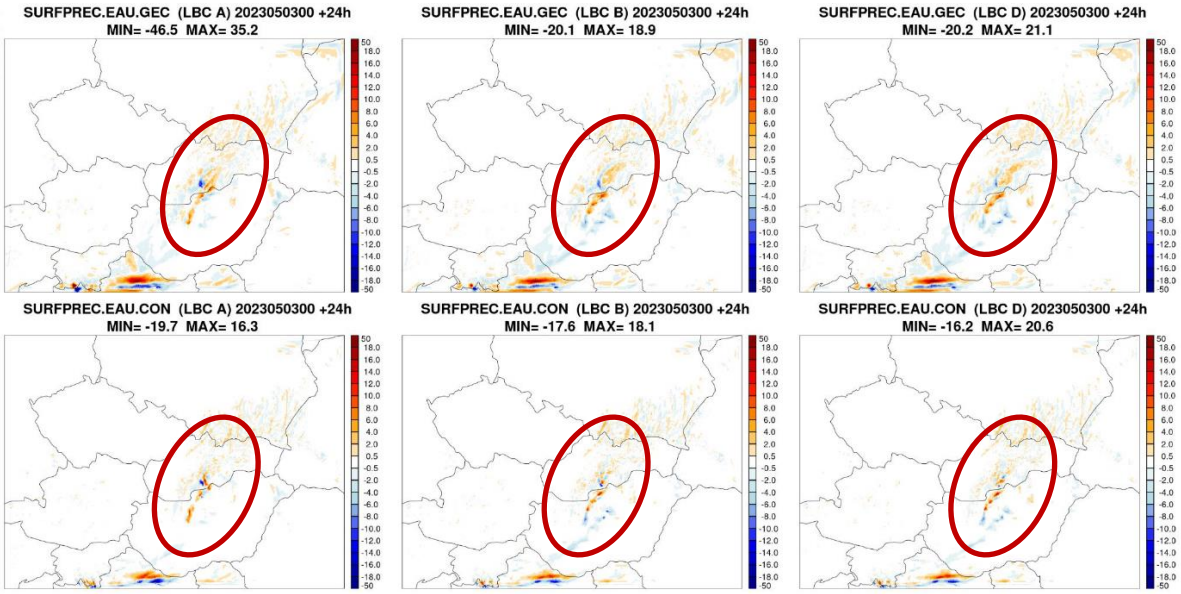

Figure 14: Difference between runs with the wider coupling zone (16gp) and with the standard coupling zone (8gp) for the three variants, A, B, D and for the large-scale precipitation (top row) and convective precipitation (bottom row).

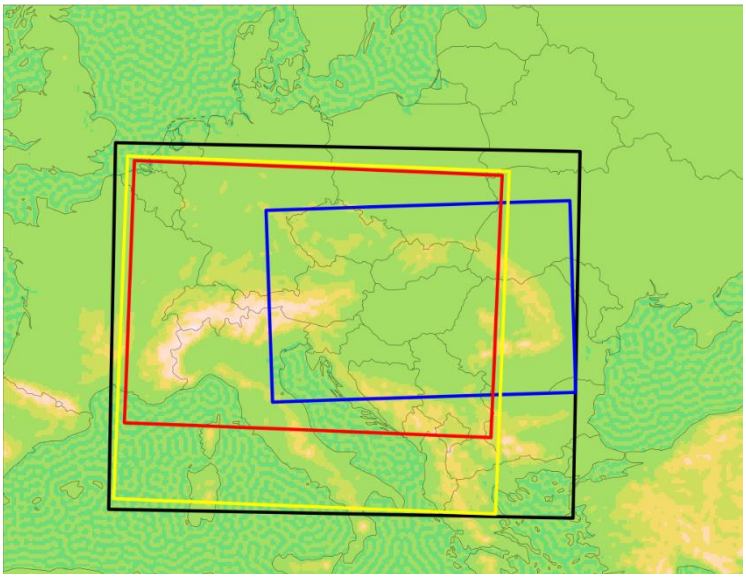

Figure 15: Domains for the current and possible future ensemble applications in the RC LACE. C-LAEF domain (red), possible extension of C-LAEF (yellow), AROME-ENS (blue) and common LBCs domain (green).

The topic is CLOSED.

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Executed efforts: 3.25 PM, local work; registered to COM3, DY1 and MQA3 work packages of ACCORD workforce summary

Documentation: The summary reports per country are available on the RC LACE web pages.

2. Documents and publications (2023)

One paper was published in MWR:

> Smolíková, P., and J. Vivoda, 2023: *Stability Properties of the Constant Coefficients Semi-Implicit Time Schemes Solving Nonfiltering Approximation of the Fully Compressible Equations*. Mon. Wea. Rev., 151, 1797–1819, https://doi.org/10.1175/MWR-D-22-0125.1.

Five reports were published on the RC LACE web pages:

> reports from new IFS LBCs testing per country and a summary report

One report is in preparation and will be published on the RC LACE web pages:

> Nika Kastelec, *Proposal for the new definition of the vertical Laplacian in the linear model*, 8pp.

3. Activities of management, coordination and communication (2023)

1) **Very-High Resolution Modelling Workshop**, SMHI, Norrköping, Sweden, 14-16 Feb 2023, presentation of AL “Dynamics settings”, participation of two LACE representatives
2) **40th LSC Meeting**, 1-2 March 2023, Bratislava
3) **3rd ACCORD All Staff Workshop**, 27-31 March 2023, Tallinn, Estonia, presentation of AL “LACE - Advances in dynamics”
4) **3D turbulence workshop**, online, 3-4 July 2023, two participants from RC LACE

4. LACE supported stays (2023)

Two research stays were executed:

1) Tuning and redesign of the horizontal diffusion depending on the scale – Mario Hrastinski (DHMZ), 0.5 PM in Prague
2) Reformulation of the NH system as a departure from HPE – Nika Kastelec (ARSO), 1 PM in Prague

5. Summary of resources/means

The efforts invested in the area of Dynamics & Coupling in the first six months of 2023 correspond to the half of efforts planned for the whole year. Two research stays were executed in the length of 1.5PM in total which is again the half of planned work. Hence, we were able to fulfil the planned activity as opposed to the previous years. Almost six PM were reported to the DE_330 project. The manpower in brackets was reported in this report but not counted to the first six months of 2023.

Task	Resources			
	Planned	Exec. Jan-Jun 2023	Stays Plan/ Exec.	DE_330
1. Vertical discretization	2	(0.5)	-	0
2. Horizontal diffusion	3	1.25	1/0.5	0
3. Time scheme	3	0	1/0	0
4. Evaluation of the dynamical core in VHR	5	5.25	-	4.75
5. Optimization of the model code	2	0	-	0
6. Basic equations	6	3.5	1/1	1
7. Coupling strategy	5	3.25	-	0
Total manpower	**26**	**13.25**	**3/1.5**	**5.75**