Working Area Dynamics & Coupling

Progress Report

Prepared by:	Area Leader Petra Smolíková
Period:	July – December 2023
Date:	22/02/2024

Progress summary

This report summarizes the work done in the Area of Dynamics & Coupling of the RC LACE from July to December 2023. Two research stays were executed in this period. One of them in the hybrid form. Other work was done locally. The work done was registered in the work packages DY1, COM2, HR, PH8 and MQA3 of the ACCORD registered workforce summary for the second 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 cycle CY49T1.

Contributors: Petra Smolíková (CHMI)

Executed efforts: 0.5 PM of local work, registered to COM2 work package of the ACCORD workforce summary

Documentation: none

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.

Status: We attempt to investigate the behaviour of total turbulence kinetic energy across resolutions. We suppose that its value should be kept while the partitioning between its components, resolved TKE and sub-grid TKE changes with resolution. We use four domains which cover approximately the same territory while the horizontal resolution is 4km, 2km, 1km and 500m, respectively.

To evaluate the resolved TKE, an original method was proposed including averaging of the three wind components in time for each grid point of the chosen sub-domain. Thus, the mean values of wind components are obtained. Then the perturbations are obtained by subtracting the mean values from the three wind components and from these perturbations the resolved TKE is evaluated. Then the space averaged values are calculated for each vertical layer and the vertical profile of finally obtained resolved TKE is plotted and compared across resolutions. From the above described method follows that the source of the perturbations is indeed not known, and all kinds of perturbations are in fact considered. Figure 1 (left) shows the value of the total TKE across resolutions. One may conclude that for 1km and 500m this value is overestimated, and the overestimation comes from the resolved part. We tried to influence

the resolved part of the total TKE with the parameters tuning of the SLHD (semi-Lagrangian horizontal diffusion). The effect in the upper troposphere is visible, but the influence of these changes is modest. See right part of Figure 1.

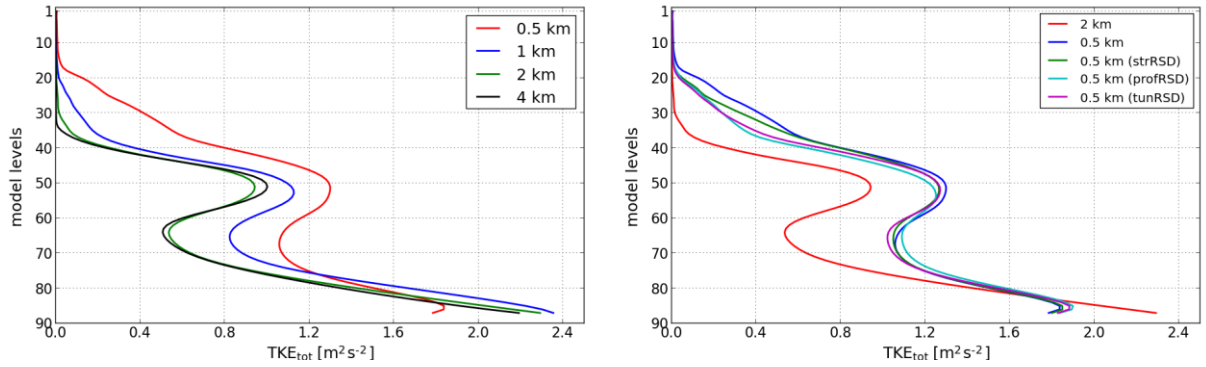

Figure 1: Vertical profile of the domain averaged total TKE. Left: across resolutions, right: with tuned SLHD.

We evaluated the influence of several choices in the sub-grid parameterizations and in the numerical diffusion setting. Among those the GWD has minor influence, while the impact of 3MT is not negligible even for Δx=500m. Then we increased the strength of reduced spectral diffusion in SLHD with a positive impact on the resolved TKE, mainly in upper troposphere. Finally, we investigated the so called 1D+2D turbulence option introduced by F. Váňa and Ivan Bašták Durán in 2012. This option is based on the horizontal derivatives of variables calculated through weights in the SL stencil.

In Figure 2 one can see that the 1D+2D (3DTURB) option influences total TKE in the right direction. The kinetic energy spectra in Figure 2, on the left, show that the small-scale spectrum is flatten giving the hope to propose even better results when properly tuned.

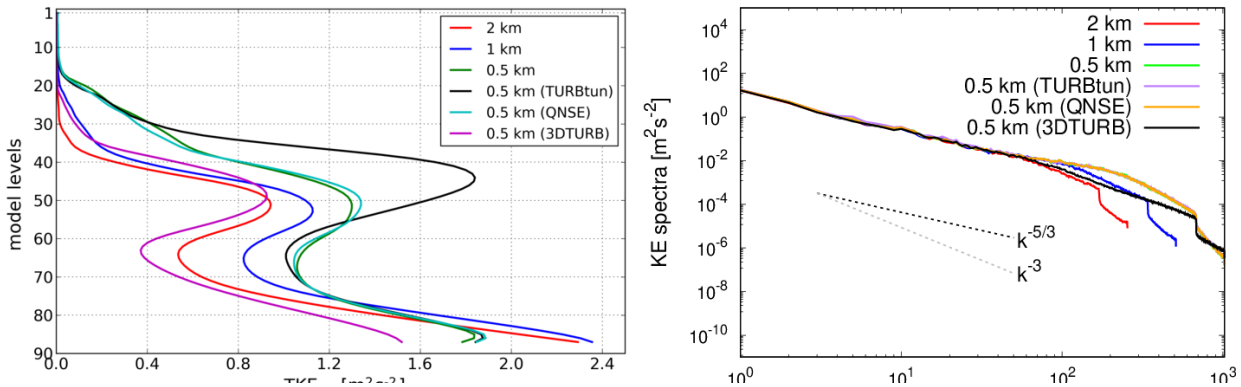

Figure 2: The influence of several choices in TOUCANS scheme on the vertical profile of the domain averaged total TKE (left) and spectra of horizontal kinetic energy close to the ground (right).

For future, we plan to investigate more the 3MT parameterizations and its proper setting in high resolutions. We would like to further investigate the impact of 1D+2D option and to combine it with horizontal features which are being introduced in the turbulence parameterization TOUCANS and which seem to be necessary for proper turbulence modeling in very high resolutions.

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

Executed efforts: 0.5 PM – research stay at CHMI, Prague; October 2023; 1 PM of local work; registered to HR and PH8 work packages of the ACCORD workforce summary

Documentation: presentation at 3D turbulence workshop, Toulouse, 4-6 Dec 2023; report from the stay available at the RC LACE web pages.

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, was executed partially in situ and partially remotely in November-December 2023.

Our aim is to find a dynamic definition of the temporal scheme that is accurate, stable and cheaper than those currently available. We follow up on the previous work reported on the RC LACE web pages. The dynamic scheme enables to choose at the beginning of each time step one of the two available schemes. We suppose that one of these schemes is more stable but

more expensive and the other one is less stable and less expensive. We would like to choose as much as possible the cheaper scheme but keep the stable integration. Previously, the choice was made between simple SETTLS and PC using NESC (predictor-corrector, with one iteration). The results showed that successful dynamic scheme can be found saving the computer resources and guaranteeing the numerical stability. We concluded that a longer test period should be considered in order to see whether the stability of the scheme and the number of time steps where the more expensive scheme is called is dependent on the meteorological context or it is more or less constant for a given domain, time step and dynamics setting used. In the current work, the main interest is in finding how such dynamical scheme can be adapted for very high resolutions. In high resolution experiments, with one step SETTLS scheme the numerical stability of the integration may not be achieved, and the iterative centred implicit

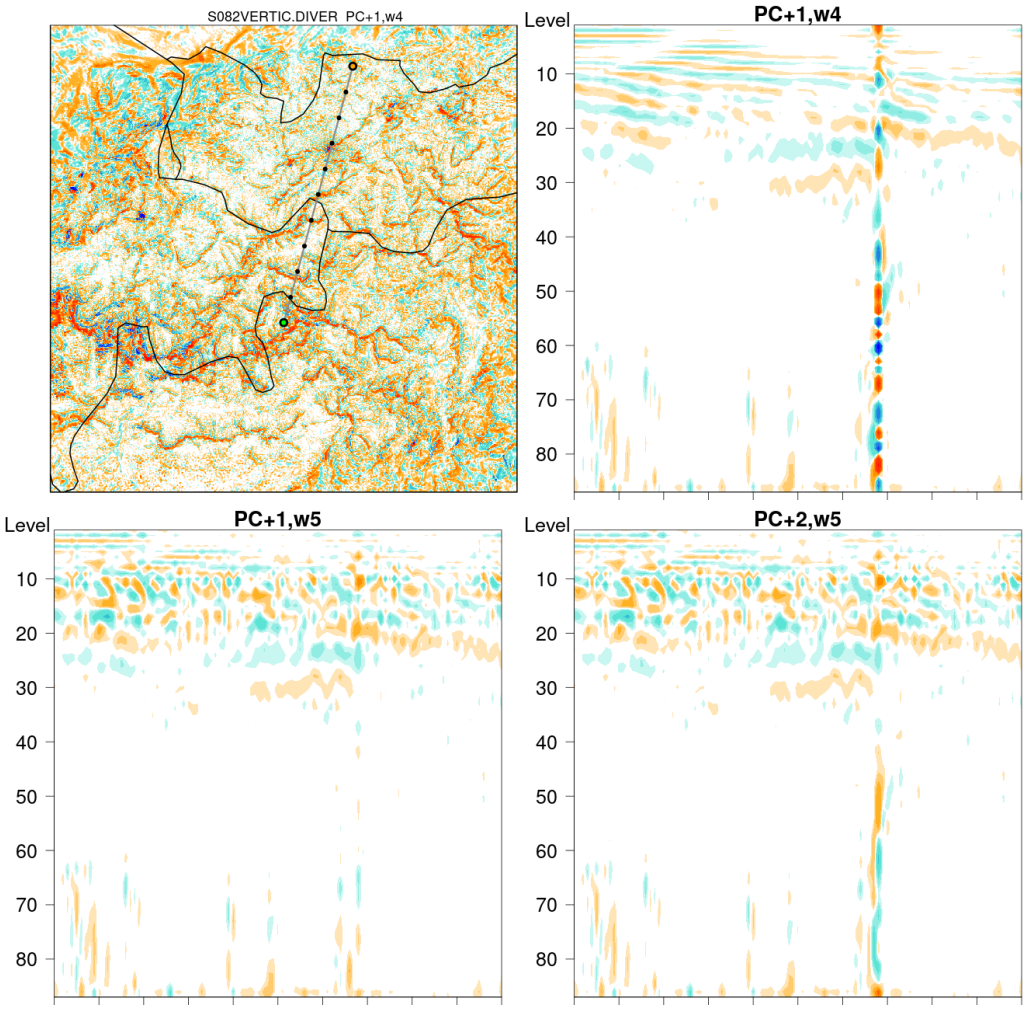

Figure 3: Vertical velocity over Alps in 200m horizontal resolution. Top left: 82nd model level and the vertical cross section line. Other pictures: vertical cross section through the indicated line for PC time scheme with one or two iterations and vertical velocity w4 or w5 (new bottom boundary condition).

scheme is a necessity. We would like to show that with the dynamical choice of the number of iterations (corrector) needed in each time step depending on a stability criterion, we can obtain cheaper and stable numerical integration.

As a testing period we have chosen two weeks between 18 August 2022 and 31 August 2022 when severe storms and wind gusts occurred over Corsica, Italy and Austria. We run a forecast for 24 hours starting from 00 UTC for each day. The selected domain covers the Alpine region near the Italian, Austrian, German and Swiss borders; we use 200m horizontal resolution and 87 vertical model layers. The model configuration is ALARO without parametrized deep convection and gravity wave drag, using TOUCANS model 2, radiation scheme ACRANEB2, microphysics and stratiform precipitation parameterizations. Horizontal diffusion is a combination of SLHD and supporting and reduced spectral diffusion, no spectral nudging is used. The leading model is ALARO CMC run on bigger domain in 500m resolution. For initialization the DFI is used after interpolation of model variables, hydrometeors and TKE to the final domain at 200m resolution. The domain has 2048 grid points in two horizontal directions with 93 grid points in the coupling zone on each domain border. Transformation to spectral space uses linear truncation for model variables while orography is smoothed more intensively with cubic truncation. We use the code version CY46t1_bf07 with modifications available in Czech operations.

We investigated the correct value of the time step such that the PC scheme with one iteration would propose numerically unstable integration at least for some cases among the testing period while PC scheme with two iterations would allow to reach stable integration in all cases. For the first day, such value was 30s and we were able to design a dynamical scheme using roughly in 60% of steps the second corrector, in 40% of steps one corrector was enough. Then, we wanted to continue for the whole chosen period. We found that for the second day in the period, 19 August 2022, we are not able to run PC with two correctors for any reasonable time step. Surprisingly, the integration was running successfully with only one corrector used in each step. After careful investigation, we found that strong chimneys are created over several grid points with the extent over almost the whole atmosphere with unrealistic values of the vertical velocity. With second corrector these chimneys were even intensified, and the integration crashed. We illustrate these results in Figure 3.

Since the location of chimneys was clearly connected to the steep orography, we decided to test the modification of Fabrice Voitus introducing new bottom boundary condition for the vertical velocity variable, so called “w5” (NVDVAR=5). The chimneys were eliminated with this method, and stable integration was achieved for one or two correctors used. Moreover, the results seem to be in close accordance suggesting the convergence of the iterative scheme in this case.

We confirmed that it is not possible to stabilize the time scheme with increased number of iterations (correctors) in case there is a strong source of instability coming for example from steep slopes of orography. In that case the additional corrector may be even detrimental for the forecast. We must look for other remedies in that case, as properly set bottom boundary condition for vertical velocity or orography included in the SI reference state. The work will continue with testing dynamical scheme with "w5" vertical velocity.

Contributors: Alexandra Craciun (NMA), Petra Smolíková (CHMI)

Executed efforts: 1 PM - a research stay at CHMI, Prague, Nov-Dec 2023, executed partially remotely; 1.5 PM of local work; registered to DY1 work package of the ACCORD workforce summary

Documentation: a report from the stay is in preparation to be published at the RC LACE web pages

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: **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: The numerical stability of the ACCORD system nonhydrostatic dynamical core is endangered as soon as the hectometric horizontal resolutions are 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: This 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 resolutions. These cases are being shared among several contributors.

VHR experiments @Geosphere Austria

The AROME model configuration based on cycle cy48t3 was run at Geosphere Austria for several cases provided by the impact model group of project DEODE. These cases were interesting for different reasons, among them heavy precipitation (130 cases), strong wind (10 cases) and frost. The domain used was centred around Austria and contained hence the central and eastern part of Alps. The numerical stability of runs was checked, and the results were evaluated against observations.

The lateral boundaries were obtained either from the operational high resolution (around 8km) forecast of IFS, or from experimental Digital Twin model run in even higher horizontal resolution (around 4km) prepared for DEODE. Simple dynamical adaptation was used, without any assimilation, nor filtering. The domain size was 1728x1250 grid points, the horizontal resolution of 500m and 90 vertical layers.

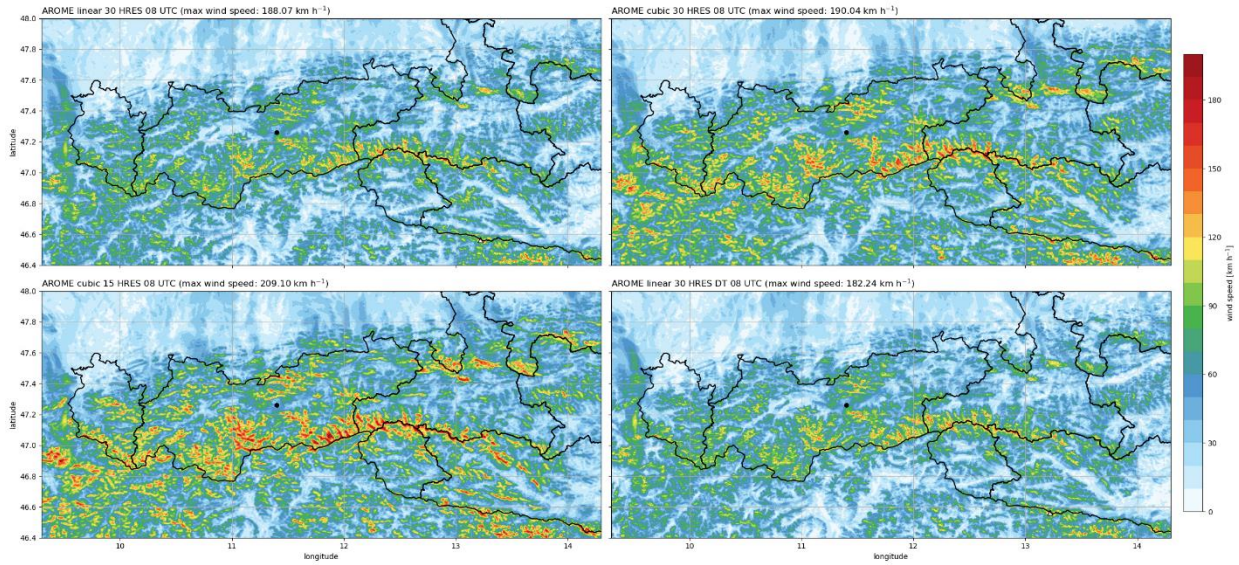

Figure 4: Top: time step of 30s, linear truncation (left) and cubic truncation (right). Bottom: shorter time step of 15s and cubic truncation (left), time step of 30s and linear truncation with coupling to HRES DT (right).

The basic dynamical setting was as follows: iterative centred implicit time scheme with two corrector steps, semi-Lagrangian scheme with SETTLS and COMAD modifications and without SLHD, only spectral diffusion and spectral nudging used to damp short waves. Subgrid parametrizations of the AROME CMC and surface scheme SURFEX were applied. Figure 4 shows the results for strong Föhn wind case of 23 October 2023 where the peak wind gusts attained the speed of 220 km/hour in the mountains and 140 km/hour in some valleys.

Tests of spectral truncation revealed that with cubic truncation and shorter time step the maxima of wind obtained are highest while linear truncation with longer time step gives smaller maxima. The influence of two different lateral boundary conditions seemed less important, but more concise testing is needed here. Similar results hold for the wind speed. Significant differences in the wind speed may be seen in upper troposphere as well. Stronger truncation and shorter time step result as well in the reduction of “SMILAG UNDERGROUND” and “ETADOT” messages. It means that the semi-Lagrangian trajectories stay inside the domain or meet better the stability constraints. With linear truncation and longer time step, the existence of these SL messages does not express in the corrupted results. Several wind time

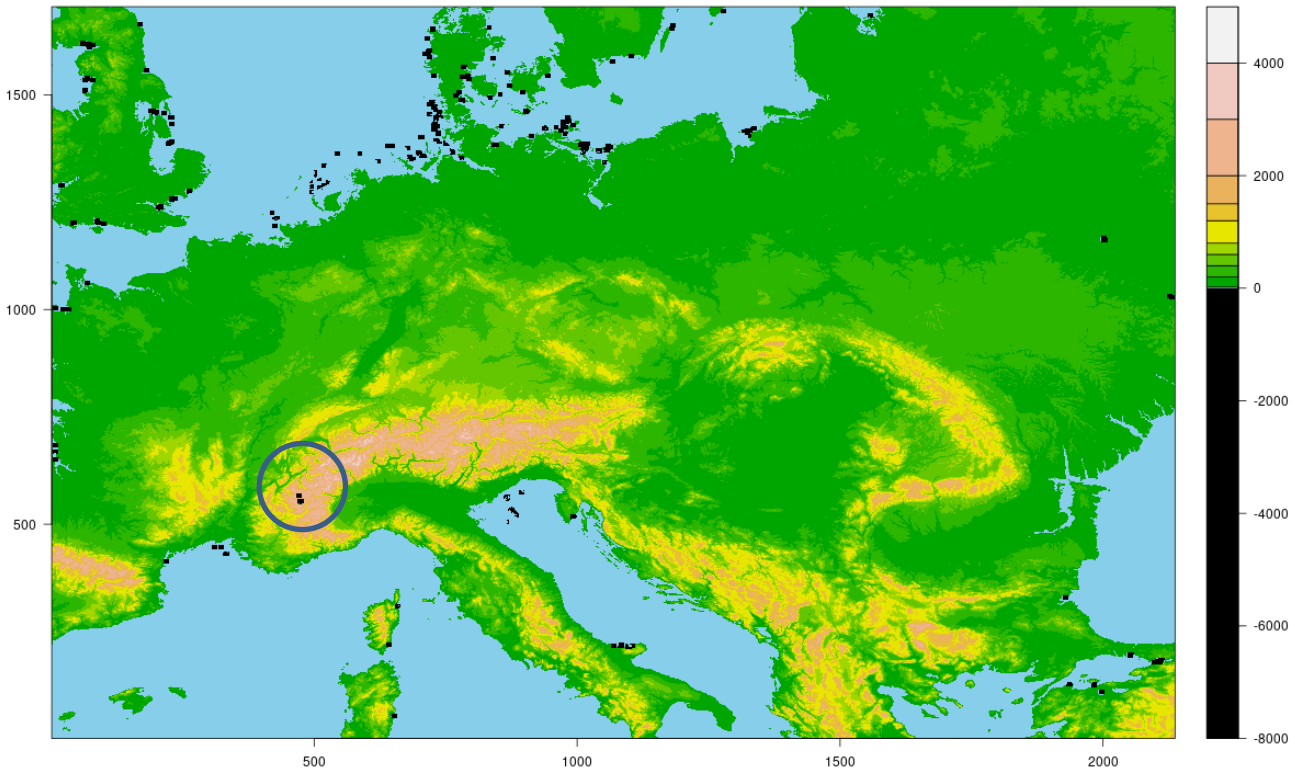

Figure 5: Orography of the domain with black squares placed on grid points having status "sea" while their surrounding grid points are "land" in PGD, blue circle denotes problematic points in the Alps.

crashes were connected to the new snow scheme and not to numerical instability coming from dynamics calculations.

VHR experiments @ CHMI

When using ECOCLIMAPII version 2.5 for the surface parameters definition, one may find incorrect values in the land-sea mask field. It may or may not demonstrate itself depending on the whole domain setting, especially the resolution and the exact domain centre position which influences the distance of the model grid points from the points in ECOCLIMAPII databases with incorrect values. The interpolation then may consider the incorrect values if the model grid point is close enough to this value. It follows that the error occurs randomly for some domains.

We demonstrate this fact with Figure 5 where we show all points which have status "sea" but there direct neighbors have status "land" in the PGD file calculated in step 2 of climake for our Central Europe domain with horizontal resolution of 1.2 km. One can see that there are two such points in the Alps and several such points close to the sea side. The orography is then modified for “sea” points and it gets very small value. If such “sea” point appears in the mountains, the “hole” made in the orography may be spectacular while for grid points where the surrounding orography is flat no big harm is probably made to the final orography field.

We show how bad the orography field may be in Figure 6. In the top line there is accidentally wrong configuration with several “sea” points in the Alps. The orography calculated in the

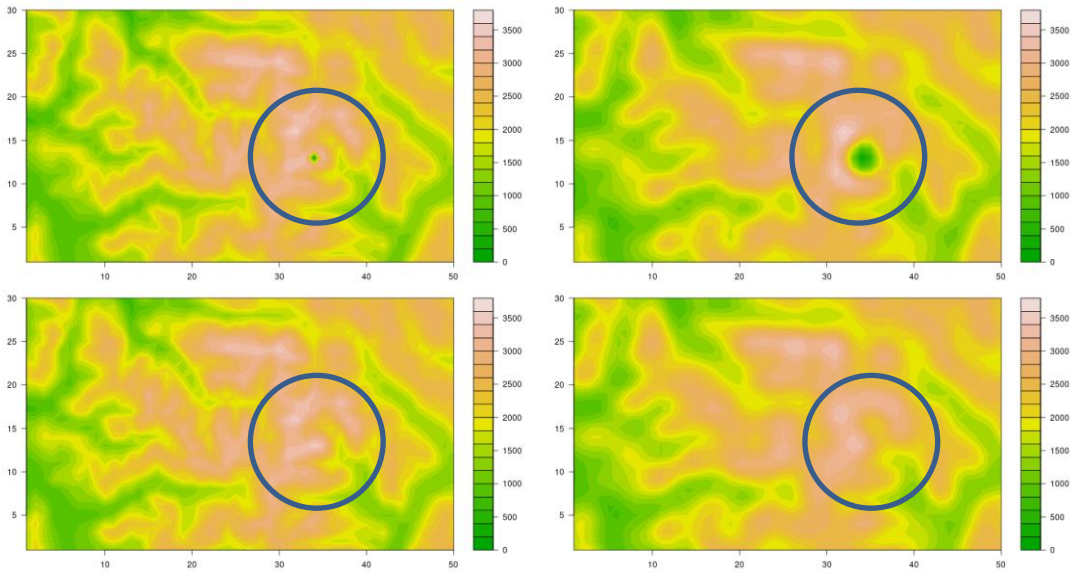

Figure 6: Orography of the subdomain in Alps. Left: from PGD after step 2 of climake. Right: from clim file after step 3 of climake. Top: using ECOCLIMAPII version 2.5. Bottom: using ECOCLIMAPII version 2.6.

second step of climake and saved in PGD is on the left and the orography contained in the clim files after the space filter is applied in the step 3 of climake is on the right. In both cases a grid point with almost zero orography appears in Alps; the width of the "crater" created is even worse after filtering.

Fortunately, this deficiency was already corrected in the later version 2.6 of ECOCLIMAPII by our colleagues. In the bottom row of Figure 6 we can find the same fields but when the version 2.6 of ECOCLIMAPII is used.

On top of that, the use case of local floods in October 2017 in the North mountain part of the Czech Republic was studied in several horizontal resolutions and model configurations for the project DE_330. It was shown that in 500m resolution the localisation and the time evolution of precipitations is better developed and the water amount in the river catchment area may be estimated more precisely.

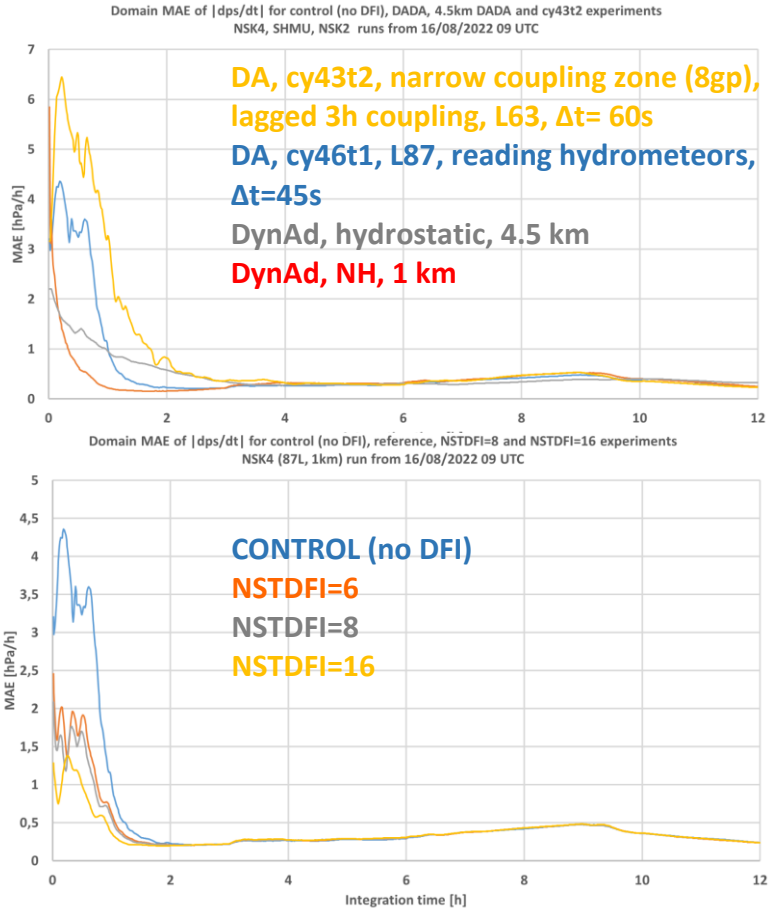

Figure 7: Domain averaged mean error of surface pressure tendency. Top: experiments with data assimilation and dynamical adaptation without DFI. Bottom: experiments with DFI.

VHR experiments @SHMI

The goal of the study was to find an optimal strategy for initialization of the RUC1 system being prepared for future operations at SHMI. The system was showing long spin-up and oscillations in the domain averaged surface pressure field tendency. It was shown previously by M. Petrovič that DFI or IAU may reduce these problems.

High (1km) resolution analysis (CANARI+3DVAR) and very short range (+12h) forecasts were run at SHMI regularly since June 2022 using short cut-off assimilated data and 1h cycling. This production is based on cy43t2 with ALARO-1vB including 3MT, ACRANEB2 and TOUCANS, model 2, without TOMs. On lateral boundaries, ARPEGE lagged files with 63 vertical layers at 1h coupling frequency are used, interpolated to 87 vertical layers. The coupling zone contains either 8 or 16 grid points on each side, respectively. The size of the C+I domain is 1024x768 grid points. The time step was the subject of considerations, ranging from 60s, 45s to 30s.

Several conclusions were made: The dynamic adaptation in the 1 km non-hydrostatic run has a shorter spin-up but higher initial anomaly than the 4.5 km hydrostatic run. Reading and interpolating hydrometeors may shorten spin-up and decrease initial anomaly. Dynamical adaptation does not show oscillations in surface pressure tendency, but the initial anomaly is

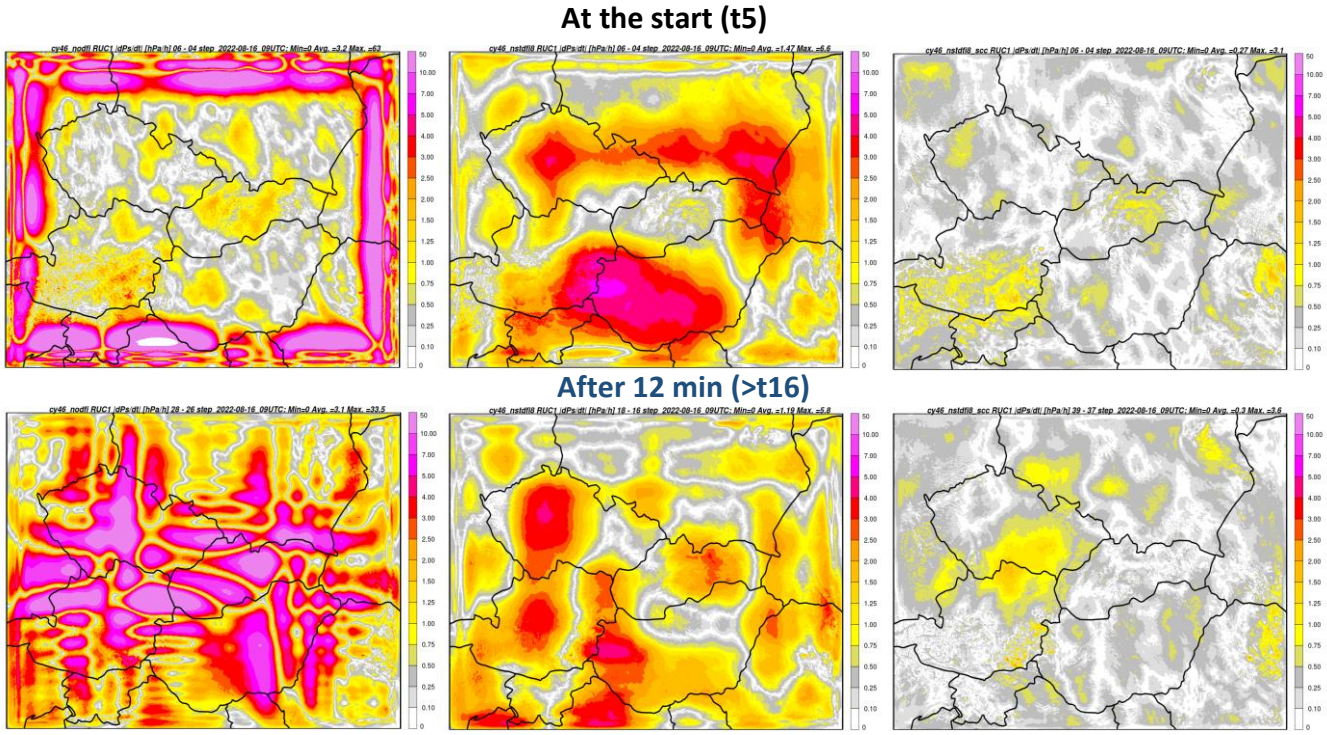

Figure 8: Surface pressure tendency anomalies. Left: time consistent coupling + no DFI; middle: time consistent coupling + DFI (NSTDFI=8); right: space consistent coupling + DFI (NSTDFI=8). Top: at time step 5, bottom: after 12 minutes or more.

even more pronounced; see Figure 7 (top) for an illustration. The application of DFI reduces the initial anomaly depending on its setting. The oscillations are generally not reduced and last approximately the same integration time. See Figure 7 (bottom) for an illustration. Generally short time window was used for DFI (NSTDFI≤16 means that the length of backward run is shorter than half an hour).

Then the spatial structure of surface pressure tendencies was investigated. It was shown that without DFI the anomalies are located at the domain borders at the beginning of the integration and propagate fast toward the domain centre, see Figure 8 (left). When DFI is applied, the spatial structure of pressure anomalies is more uniform, and the maxima are smaller; see Figure 8 (middle column). The application of space consistent coupling instead of time consistent coupling version reduces the initial pressure tendency anomaly almost entirely; see Figure 8 (right). The IAU run shows worse results probably due to inconsistencies

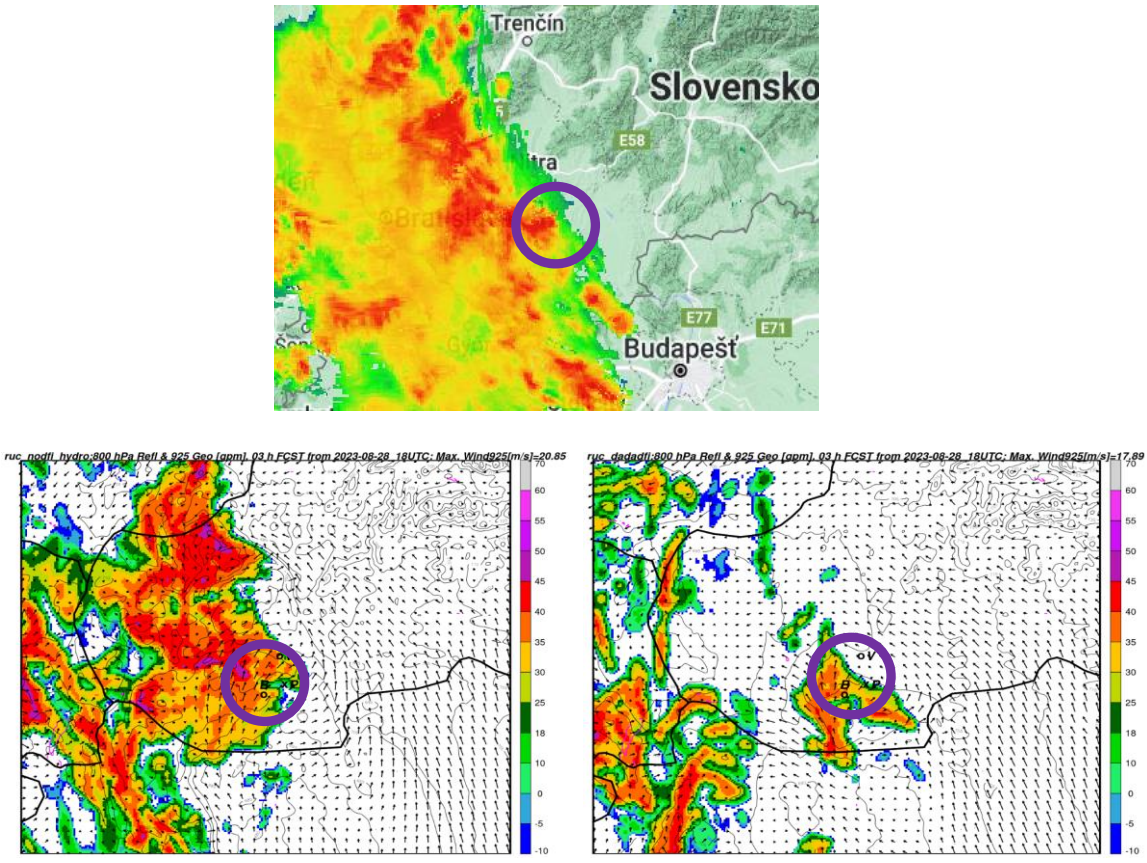

Figure 9: Radar reflectivity for 18 August 2023 21 UTC. Left: measured with CAPPI, middle: forecast 800hPa +3h, data assimilation and no DFI, right: forecast 800hPa +3h, dynamical adaptation with DFI (NSTDFI=8). Arrows show wind speed and direction at 925hPa. The circle denotes the place where the windstorm appeared.

between the guess and the analysis or LBCs.

The influence of DFI was studied on the differences in temperature field. At the beginning of integration, the effect is strongest close to the surface and at the lateral boundaries. Later in the integration the differences are more localized due to the sensitivity of deep convection or other parameterisations to small perturbations and shifts in values.

Further, simulated radar reflectivity was studied for several cases. Dynamical adaptation with DFI forecasts less convective activity than the runs using assimilation, but the effect on the rainfall intensity is not substantial; see Figure 9. Moderate damping against the reference was found when using IAU.

The topic is ONGOING.

Contributors: Mario Hrastinski (DHMZ), Maria Derková, André Simon (SHMI), Radmila Brožková, Ján Mašek, Petra Smolíková (CHMI), Phillip Scheffknecht, Christoph Wittman (Geosphere Austria)

Executed efforts: 10.25 PM of local work; 6.25 PM 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 deliverables prepared for 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.**

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.

Status: The blended NH/HY dynamics developed previously was made available via phasing to the cycle CY49T1.

The topic is ONGOING.

Contributors: Petra Smolíková (CHMI)

Executed efforts: 0.5 PM of local work; registered to COM2 work package of the ACCORD workforce summary

Documentation: none

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: We aimed for evaluation of the benefit of one hour coupling frequency on lateral boundaries for several domains, mainly future Croatian operational domain, current Czech operational domain and 200m experimental Alpine domain. To find an appropriate case which could reveal such benefit, we searched through the values of MCUF array in the coupling zones of the domains of interest to find dates with highest maxima or lowest minima. See [1] for details. We searched in ARPEGE LBC files being issued for each hour of the first 24 hours of the 00UTC run, for each day in years 2022 and 2023. We found several promising dates and expect to run the forecast for them and evaluate it soon. The maximum absolute values of

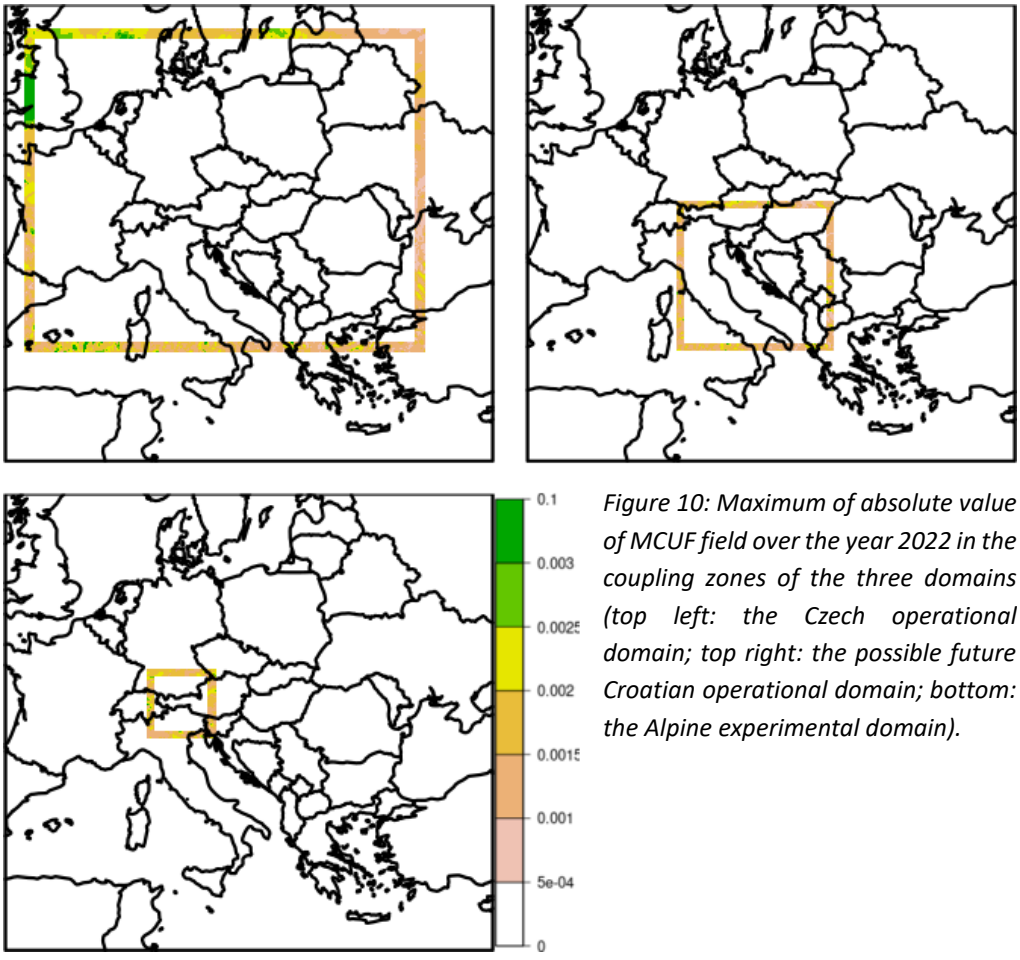

Figure 10: Maximum of absolute value of MCUF field over the year 2022 in the coupling zones of the three domains (top left: the Czech operational domain; top right: the possible future Croatian operational domain; bottom: the Alpine experimental domain).

MCUF field from the above-mentioned ranges of the whole year 2022 are depicted in Figure 10 for all three domains.

[1] Martina Tudor, Methods for automatized detection of rapid changes in pressure applicable to lateral boundary condition fields for NWP limited area models, available through www.researchgate.net

Contributors: Ana Sljivic, Bruno Ćurjurić (DHMZ), Petra Smolíková (CHMI)

Executed efforts: 0.75 PM of local work

Documentation: none

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: **The topic is CLOSED.**

2. Documents and publications

One paper is being prepared for the publication in QJRMS:

> H. W. Lean, N. E. Theeuwe, M. Baldauf, J. Barkmeijer, G. Bessardon, L. Blunn, J. Bojarova, I. A. Boutle, P. A. Clark, M. Demuzere, P. Dueben, I.-L. Frogner, S. de Haan, D. Harrison, Ch. van Heerwaarden, R. Honnert, A. Lock, Ch. Marsigli, V. Masson, A. Mccabe, M. van Reeuwijk, N. Roberts, P. Siebesma, P. Smolíková, X. Yang, *The hectometric modelling challenge: Gaps in the current state of the art and ways forward towards the implementation of 100 m scale weather and climate models*, in preparation

One report was published on the RC LACE web pages:

> Mario Hrastinski: *Development of the sub-kilometer ALARO Canonical Model Configuration*, report from a stay, May and Oct 2023

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

> Alexandra Craciun, *Dynamic definition of the iterative time schemes*, report from a stay, Nov 2023

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

1) **41th LSC**, 11-12 Sep 2023, Prague, Czech Republic

2) **45th EWGLAM - 30th SRNWP Workshop**, 25 - 28 Sep 2023, Reykjavik, Iceland, presentation of Petra Smolíková: *Dynamics in LACE - towards hectometric scales*

3) **3D turbulence workshop**, 4-6 Dec 2023, Toulouse, France, two in situ participants from RC LACE, presentation of Mario Hrastinski and Petra Smolíková: *Turbulence considerations across scales in ALARO*

4. LACE supported stays

Two research stays were executed in the second half of 2023:

1) Mario Hrastinski, Tuning and redesign of the horizontal diffusion depending on the scale, 0.5 PM in Prague (Oct 2023), second part

2) Alexandra Craciun, Dynamic definition of the iterative time schemes, 0.5 PM in Prague (Nov 2023) + 0.5 PM remote stay (Dec 2023)

5. Summary of resources/means

The efforts invested in the area of Dynamics & Coupling of RC LACE in the whole year 2023 exceed slightly the efforts planned. There was a strong shift to the experiments in the very high resolutions where we have invested three times more workforce than planned previously. These efforts are needed to fulfill the goals of the project DEODE. Three research stays were executed in the length of 3 PM in total, two weeks of that remotely. This represents exactly the commitments planned for 2023. We contributed to the work packages DY1, HR, COM2, MQA3, PH8 and some work was committed as NOREF to the ACCORD work force statistics. Together 12 PM were reported to the DE_330 project.

Task	Resources					
	Planned	First half 2023	Second half 2023	Together executed	Stays	DE_330
1. Vertical discretization	2	0	0.5	0.5	-	0
2. Horizontal diffusion	3	1.25	1.5	2.75	1/1	0
3. Time scheme	3	0	2.5	2.5	1/1	0
4. Evaluation of the dynamical core in VHR	5	5.25	10.25	15.5	-	11
5. Optimization of the model code	2	0	0	0	-	0
6. Basic equations	6	3.5	0.5	4	1/1	1
7. Coupling strategy	5	3.25	0.75	4	-	0
Total manpower	**26**	**13.25**	**16**	**29.25**	**3/3**	**12**