Working Area Dynamics & Coupling

Progress Report

Prepared by:	Area Leader Petra Smolíková
Period:	September - December 2022
Date:	26/2/2023

Progress summary

This report summarizes the work done in the Area of Dynamics & Coupling of the RC LACE from September to December 2022. Two research stays were executed in this period. A valuable work was done locally as well.

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 topic is PENDING.**

Executed efforts: none

Subject: 1.2 Modularization of vertical discretization

Description and objectives: The influence of a vertical discretization on stability and accuracy of the model integration is still not well understood. This task incorporates two parts, one technical – to modularize the vertical discretization from other parts of the dynamics; and second scientific, to understand better the influence of vertical levels definition on the behaviour of the model. It is a known fact that SL interpolations are less accurate when applied in terrain following vertical coordinates then in smooth pressure levels (Park et al., 2019). The usage of hybrid levels up to the stratosphere is a common practise in our community. However, it can be a source of noise in the upper model levels. This undesirable phenomenon can be simply pacified by using pressure levels already from the middle troposphere and higher. Such a choice could have a positive influence on the quality of the upper level turbulence (CAT) prediction and it could possibly avoid the generation of vertical chimneys in the vertical

velocity field observed often over an orography. This could have as well a positive impact on precipitation field which may become smoother. Hence, we propose to investigate the influence of "hybridism" on the quality of the model prediction and to try to find an optimal choice for vertical coordinate setting.

[S.-H. Park, J. B. Klemp, and J.-H. Kim, *Hybrid mass coordinate in WRF-ARW and its impact on upper-level turbulence forecasting*, MWR, in press, 2019]

The topic is PENDING.

Executed efforts: 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: After activity in the first part of 2022, this topic was pending for the last months of the year. Several participants from RC LACE countries were attending the 3D Turbulence Working Week being held in Wien in October 2022.

Executed efforts: none

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

Subject: 3.2 The trajectory search in the SL advection scheme

The topic is CLOSED.

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

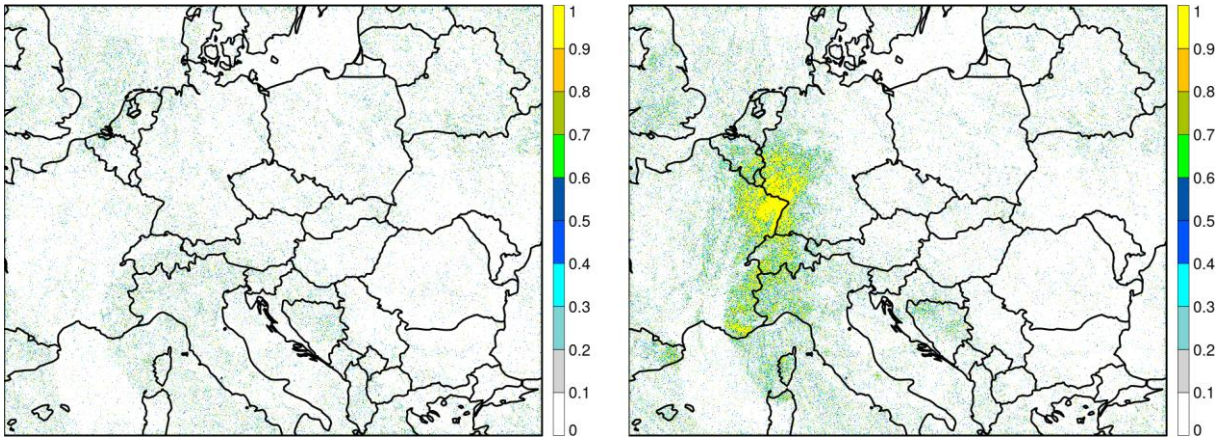

Figure 1: The stability characteristic at the lowest model level for a time step which will need only SI scheme and one which needs one PC iteration to stabilize the integration.

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: Previous study from 2019 was dedicated to find a combined SETTLS/NESC scheme based on an instability condition, computed in each grid point (see report from the stay of Alexandra Craciun in 2019). Now, we would like to find a global stability criterion such that a choice between simple SI scheme with SETTLS evaluation of the non-linear terms and iterative centred implicit scheme with one iteration and NESC evaluation of the non-linear terms can be made at the beginning of every time step. The instability diagnostic proposed is based on the time derivative of the vertical divergence non-linear residual in every grid point. The percentage of grid points for which this characteristic exceeds a given threshold is evaluated and the decision on the time scheme used is done accordingly.

The method was implemented in the ACCORD codes based on cy46t1 and then tested on two real cases. The cases setting was similar as the Czech operational one, using the Czech operational domain in 2.325km horizontal resolution and 87 vertical levels, using ARPEGE coupling files every 3 hours and initial file of the Czech operational suit (3DVAR blending method and CANARI for surface parameters). The physical package used is ALARO with TOUCANS, ACRANEB-2 and 3MT. Non-hydrostatic dynamics with the time step of 90s is used. Both cases were known to be dynamically unstable when SI scheme with SETTLS evaluation of the non-linear terms was used. Both experiments showed that a CPU time used to achieve 72 hours forecast may be decreased with the dynamic choice of the time scheme with results of the comparable quality as the reference experiment (NESC+PC at each time step). The possible

savings in the CPU time used are about 15% compared to NESC+PC. These results are illustrated in the following figures.

Executed efforts: 3PM, from that 1PM - the research stay of Alexandra Craciun at CHMI, 2 PM

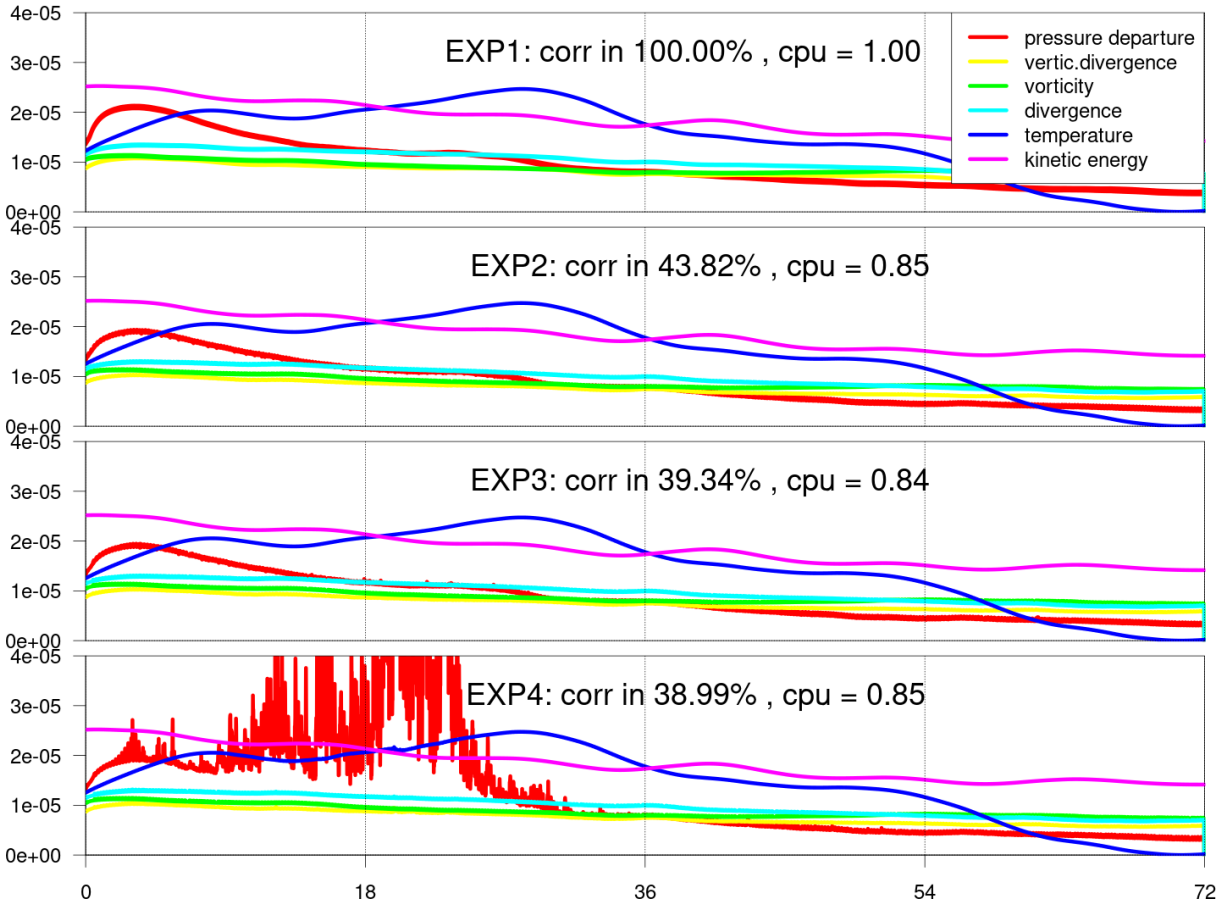

Figure 2: The time evolution of spectral norms averaged over the whole domain for NESC+PC (top) and three different values of the threshold used for decision on the time scheme used (value 40,50,60). One can notice that the cost of all three experiments (EXP2, EXP3, EXP4) is similar, the number of corrector steps needed is as well similar, but the scenario at which time step the corrector is applied differs and the stability is better ensured for EXP2 and EXP3. This is illustrated on the pressure departure spectral norm time evolution (the red curve).

of local work.

Documentation: the report is under preparation and will be published soon on the RC LACE web pages

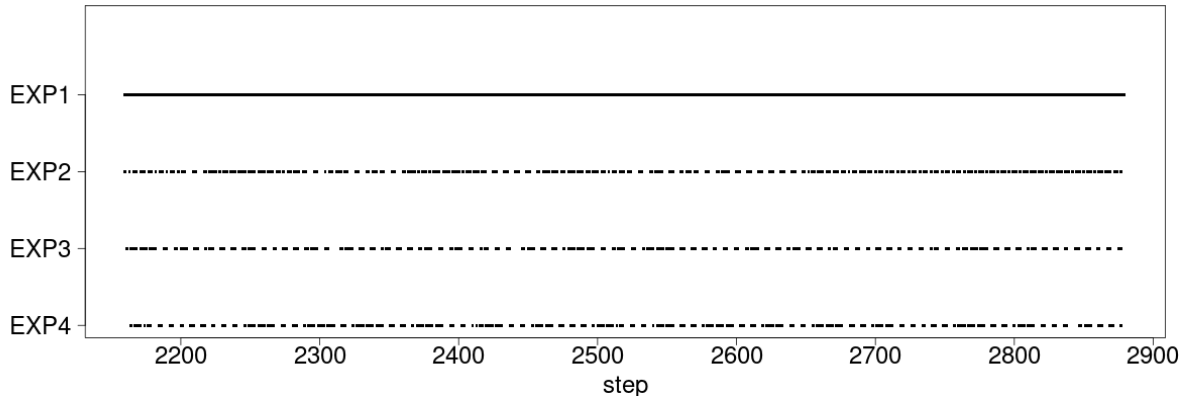

Figure 3: Three different scenarios of the usage of the simple SI scheme and PC scheme, black point indicates that at the given time step the PC scheme was applied, white space means SI+SETTLS. Thus more white means earlier devivery. The scenarios correspond to experiments EXP1, EXP2, EXP3, EXP4 from Figure 2.

Subject: 3.4 Terms redistribution through new vertical motion variables

Description and objectives: Motivated by the work of Fabrice Voitus which was 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. Several new formulations of vertical velocity were already proposed in 2018 and implemented in the model code. Parallelly, new vertical motion variable was implemented in Toulouse by F.Voitus. Its usage with VFE discretization will be studied and code will be modified.

Status: The topic is PENDING.

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 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.

Executed efforts: none

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

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: With the foreseen project DEODE where several RC LACE countries are involved, experiments in even higher resolution of 100m are expected to be prepared as well as more convenient set ups around 500m of horizontal resolution. The new options in dynamics will be tested in these scales expecting better stability results to be achieved. Some experiments have already started with a domain over Alps in 150m horizontal resolution prepared by Météo-France. The aim is to enhance the stability of the proposed time scheme which is seen as insufficient. Moreover, a setup for an experimental domain over Central Europe covering the Alps was prepared with the following slightly less ambitious parameters: horizontal resolution of 890m, 1536x1250 grid points, 87 vertical levels. With these parameters, PGD tool and e923 configuration are able to run without modifications for parallelisation and further changes which would be needed for larger domains. The problem needs more investigation and a transfer of expertise. Moreover, these processes will be needed in the DEODE project and thus should receive the needed attention otherwise the usage of too small domains may deteriorate the obtained results.

Some experimental domains were prepared at several Met Services, 500m domain over Central Europe at CHMI, 500m VORTEX domain over Austrian Alps etc. The process of PGD files creation was discussed with our colleagues from Météo France, where a parallel version of the code was prepared based on cycle CY48t1. To finish PGD file preparation and e923 procedure for clim files preparation for large domains (roughly bigger than 1 million grid points) some code modifications are necessary, to increase the size of allocated arrays and to avoid extremely long loops (over the whole horizontal domain). Many different tools exist for this task and the experience with them is individual. Some unification in this part would be useful.

The topic is ONGOING.

Contributors: Petra Smolíková (CHMI)

Executed efforts: 0.75 PM of local work

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-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: We have to admit that not much effort was invested in this topic in the RC LACE. On the other hand, since the dynamical kernel is being shared with global models of ECMWF and Météo France and single precision runs of EPS are foreseen in these institutions, a progress was being made there. It was indicated that double precision is needed in several parts of the code as for example in VFE. Hence, to progress in this topic we may propose some tests to assess the performance of SP and DP runs.

Status: The topic is PENDING.

Executed efforts: none

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 a new parameter ε (ε = 1 NH core, ε = 0 HY core). Then all computations of the dynamical core can be treated in a unified code. Moreover, this parameter ε 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 forces were driven to the publication of the obtained results in Monthly Weather Review. A paper submitted to MWR was revised. The main contributor Jozef Vivoda left SHMI (and RC LACE) for his new position in the ECMWF project DestinE.

On top of that, the stability analysis in the context of constant slope orography for several time scheme was prepared by our new Slovenian colleague following the method published in Bénard et al. (2005). This environment may be used to assess the behaviour of the hybrid

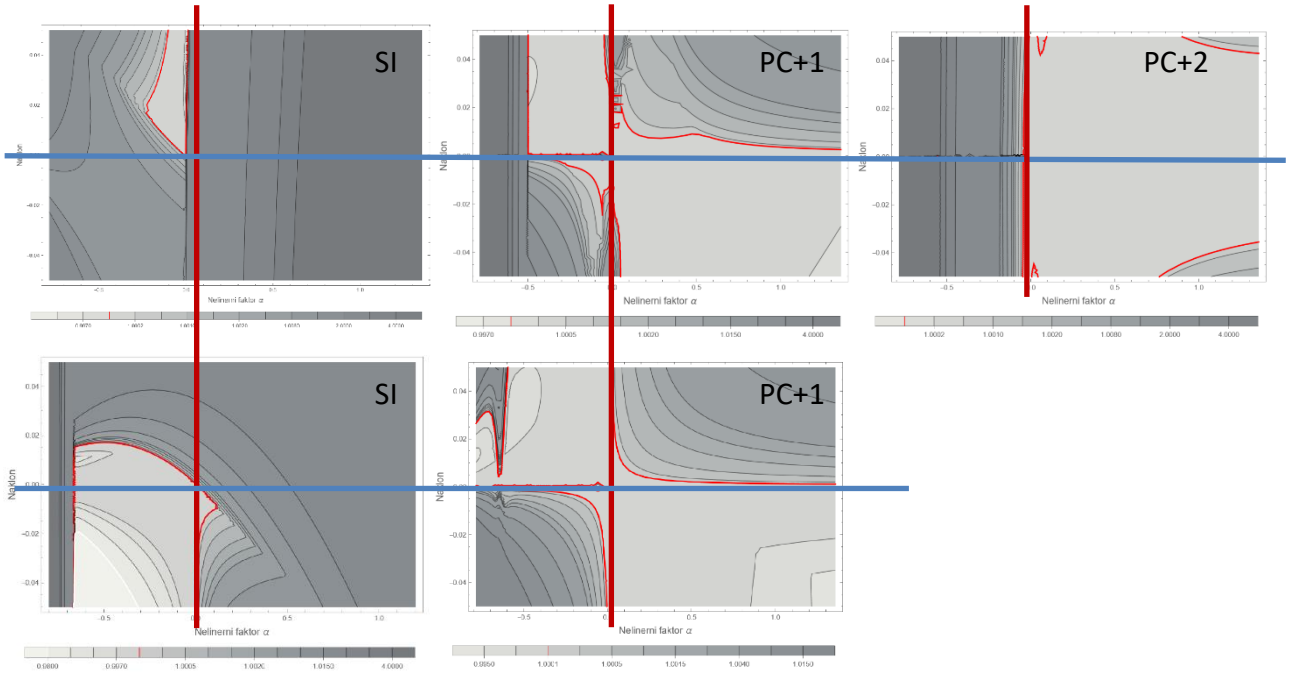

Figure 4: Stability analysis results: the growth rate in dependence on the nonlinearity factor $\alpha=(T- T^*)/T^*$ (x-axis) and the slope (y-axis). In the left part of figures the real temperature is lower then the reference T^* and in the right part $T>T^*$. One can conclude that for the PC scheme with one iteration either lower or higher values of T^* are beneficial for stability depending on the slope. Thus, it is hard to be satisfied. Red lines denote the border between the area where $T<T^*$ and where $T>T^*$. Blue line denotes the border for negative and positive slopes, both appear in the model orography. First line is with $SITRA=T_A^*= T^*=SITR$, second line with $SITRA=T_A^*<T^*=SITR$. For PC with two correctors, $T> T^*$ could be beneficial for all slopes which is in contradiction to the current setting (usually $T^*=350K$).

system with control parameters (as proposed when NH system is reformulated as a departure from HPE) in the presence of constant slope orography. The results were published in a master thesis of Nika Kastelec, now from ARSO. See Figure 3 for an illustration of obtained results.

Bénard P., Mašek J., Smolíková P., *Stability of leapfrog constant-coefficients semi-implicit schemes for the fully elastic system of Euler equations: Case with orography*, 2005, MWR Vol.133, 1065-1075.

The topic is ONGOING.

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

Executed efforts: 2 PM of local work

Documentation: a manuscript of the paper submitted to MWR, master thesis of Nika Kastelec about stability analysis with orography

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.**

Executed efforts: none

Subject: 7.2 Frame approach in the LBC files

Description and objectives: 1 hour coupling frequency is believed to be an interesting option, but the current LBC files prepared from ARPEGE for the LACE domain are "huge" while our HPCs are "fast". It follows that we are not able to get the LBC files quickly enough to use them operationally in high frequency (1h). We might think about frames implementation in FA format and about connected problems (LBC transformed to grid point space, the central part removed and just the frame distributed, central values smoothly completed, the whole field biperiodized and transformed to the spectral space). Such procedure must keep the values in the coupling zone reasonably precise. We would like to start to design such frames and to test

them. These activities must be strongly coordinated with our partners, mainly Météo France, as the producer of LBC files.

Status: During the first stay in 2021, the full LBC files were prepared first in the fine resolution (2.3km) over the target domain (Czech operational one) and in grid-point representation of all fields. Then the inner part was removed and filled it with artificial values. Then the results of forecast run with LBC files prepared in the described way were compared with those run with the reference coarse resolution LBC files. The correspondence of the forecasts was good, no degradation of its quality was detected, but the main target, which was the compression of the LBC files, was not reached.

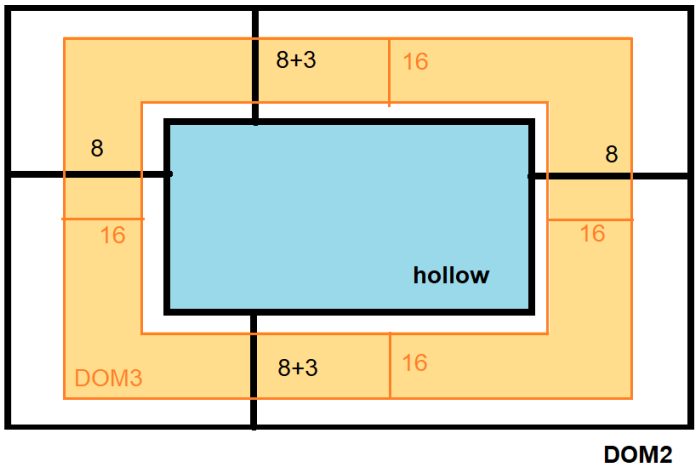

Figure 5: The coupling zone of the domain in the target fine resolution must fit into the frame prepared from the coarse resolution LBCs.

The aim of this year work was to check whether it is possible to frame LBC files in grid-point representation already at an earlier stage of processing, when they are still in coarse resolution. We prepare the LBC files in grid-point representation, remove the inner part of the domain (so called *framing* or *hollowing*), transmit the LBC files to the final destination (National Meteorological Service) and reconstruct fields in the whole domain. We aim for the verification scores of the forecast run using these LBC files not being worse than for the reference experiment with the original LBC files.

A testing period of 14 days (1-14 November 2021) was chosen when a low-pressure system is passing through the central part of the domain. Forecasts for +72 hours were run once a day starting from 0UTC. The basic setting of the experiment and the initial files were those of the Czech operational suite. Forecasts were evaluated point-wise against observations using objective scores (e.g. BIAS, RMSE, STDE). No systematic degradation of results was observed. Locally, there were differences detected in the individual fields which were not significant. The details may be found in the report.

Then we evaluated theoretically and in practice the reduction in size of the transferred LBCs. For file compression we used either the packing method available in the fullpos in recent cycles (NFPGRIB=140) or the standard gzip software. This is summarized in the following table. The reduction is substantial.

Table 1: Comparison of the total file size for two different packing methods.

	input size	output size	compression [%]
fullpos with NFPGRIB=140	270 336 B	122 880 B	54,5%
gzip (with default compression level)	270 336 B	35 612 B	86,8%

Obviously, national weather services can benefit from the method only if the process of framing will be carried out on the side of the partner who prepares the global forecast and produces the LBC input (MF and ECMWF) already before the transfer. What should be also taken into consideration at this stage is that every national weather services has its own local domain. So the process of preparing and transferring LBC files would have to be more "personalized".

Contributors: Gabriel Stachura, Petra Smolíková

Executed efforts: 2PM, 1PM from that - research stay of Gabriel Stachura at CHMI (October 2022), 1PM of local work

Documentation: report is published on the RC LACE web pages

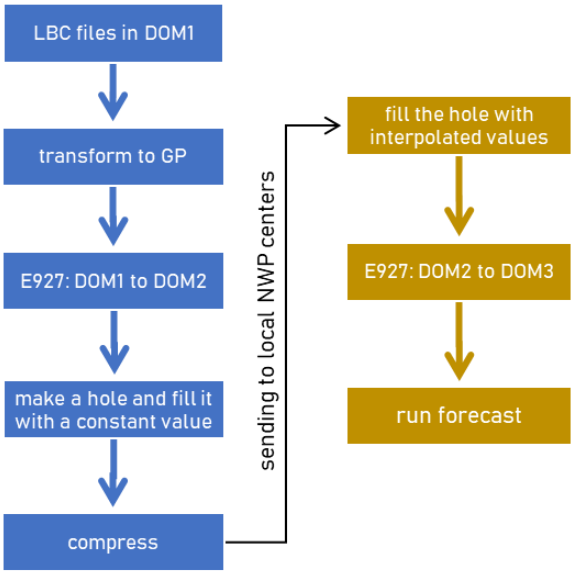

Figure 6: The process of preparation of the LBCs using the frame approach. DOM1 is the Telecom domain, DOM2 an appropriate domain for framing and DOM3 the target fine scale domain.

Subject: 7.3 The impact of higher truncation in LBC files

Description and objectives: Another way how to decrease the size of LBC files while hoping in keeping the quality of the final forecast is to increase truncation of spectral fields in LBC files (quadratic, cubic etc.). This will be tested.

Status: **The topic is PENDING.**

Executed efforts: 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 Croatian operations. Problems with the performance of the e903 procedure were detected and need to be solved.

Status: To be able to fulfil the main objective of this topic we need an agreement among the RC LACE countries on the output LBC files produces at ECMWF concerning grid spacing (currently Δx=15.4 km and preliminary idea for the new files Δx is 8.5 km) and vertical levels placement (currently there are 60 levels and preliminary idea is to have 137 levels like the native IFS files). The size of the new LBC files has to be considered as well. As soon as the agreement exists, testing files have to be prepared and the interested RC LACE members may test them on cases with fast-moving fronts or cyclones and considering the impact of coupling frequency as well.

Status: A questionnaire was prepared for the RC LACE members to gather the information on their needs. **The topic is ONGOING.**

Executed efforts: 0.25 PM, local work

Contributors: Petra Smolíková, all LTMs

Documentation: The summary is available on the RC LACE web pages.

2. Documents and publications (2022)

One paper was submitted to MWR:

Jozef Vivoda and Petra Smolíková, *Stability properties of the constant coefficient semi-implicit schemes solving equation system with controlled nonhydrostatism,* in preparation.

Three reports are in preparation or being published on the RC LACE web pages:

1) Mario Hrastinski, *Implementation of the quasi-3D turbulence scheme within the ALARO Canonical Model Configuration*, 11pp.
2) Alexandra Craciun, *Dynamic definition of the iterative time schemes*, 9pp.
3) Gabriel Stachura, *Frame approach in coupling*, 15pp.

One master thesis (magistrsko delo) was defended at the University of Ljubljan:

Nika Kastelec, Analiza stabilnosti nehidrostatičnega modela za napovedovanje vremena

3. Activities of management, coordination and communication (2022)

1) **FVM LAM**, online meeting, 24 February 2022
2) **38th LSC Meeting**, virtual, 8-9 March 2022
3) **Second ACCORD All Staff Workshop 2022**, virtual, 4-8 April 2022 – presentation of AL "RC LACE: Coupling & Dynamics"
4) **Dynamics day,** online, 2 June 2022
5) **39th LSC Meeting**, virtual, 19-20 September 2022
6) **44rd EWGLAM and 29th SRNWP joined meetings**, 26-29 Sept 2022, Brussels – presentation of AL "First attempts to implement horizontal features to the turbulence scheme TOUCANS of ACCORD/ALARO"
7) **3D turbulence Working Week 2022**, Wien, Austria, 12-14 October 2022, participation of Mario Hrastinski with the presentation about "Horizontal features of the turbulence scheme TOUCANS"
8) **100m scale workshop,** KNMI, DeBilt, Netherlands, December 2022 – participation of AL

4. LACE supported stays (2022)

One research stay was cancelled due to unavailability of the dedicated staff. (Jozef Vivoda left SHMI for his engagement in DestinE project.) Three research stays were executed:

1) Tuning and redesign of the horizontal diffusion depending on the scale – Mario Hrastinski (DHMZ), 1 PM in Prague
2) Dynamic definition of the iterative time schemes - Alexandra Craciun (ANM), 1 PM (November 2022) in Prague
3) Frame approach in the LBC files – Gabriel Stachura (IMGW), 1 PM (October 2022) in Prague

5. Summary of resources/means

The efforts invested in the area of Dynamics & Coupling in 2022 were again limited. We suffer from the drain of workforces by other projects, mainly DestinE. On the other hand, one student joined us for theoretical analytical work in Slovenia. We were able to commit three quarters of the work we planned. Three research stays were executed in the length in total of 3PM. The work done in the reported period (Sep-Dec 2022) is highlighted in yellow, the work done partially in the reported period is highlighted in light yellow.

Task	Subject		Resources		
			Planned	Executed	Stays Plan/Exec
1. Vertical discretization	1.1	Design of VFE in NH model	1	0.5	-
	1.2	Modularization of vertical discretization	2	0	-
2. Horizontal diffusion	2.1	Tuning and redesign of the horizontal diffusion depending on the scale	2	3	1/1
3. Time scheme	3.1	Generalization of the semi-implicit reference state	2	0	-
	3.2	The trajectory search in the SL advection scheme	0	0	-
	3.3	Dynamic definition of the iterative time schemes	3	3	1/1
	3.4	Terms redistribution through new vertical motion variables	2	0	-

4. Evaluation of the dynamical core in very high resolutions	4.1	Tuning of dynamical adaptation of the wind field at different resolutions	1	0	-
	4.2	Upper boundary condition	1	0	-
	4.3	Experiments in very high resolution	1	1.25	-
5. Optimization of the model code	5.1	Single precision	1	0	-
	5.2	The FFTW algorithm	1	0	-
6. Basic equations	6.1	Reformulation of the NH system as a departure from HPE	4	10	2/0
7. Coupling strategy	7.1	The impact of higher coupling frequency	2	0	-
	7.2	Frame approach in the LBC files	2	2	1/1
	7.3	The impact of higher truncation in LBC files	1	0	-
	7.4	Preparation of new LBC files from IFS	1	0.25	
Total manpower			**27**	**20**	**5/3**