Working Area Dynamics & Coupling

Progress Report

Prepared by:	Area Leader Petra Smolíková
Period:	Jan-Aug 2022
Date:	14/9/2022

Progress summary

This report summarizes the work done in the Area of Dynamics & Coupling of the RC LACE from January to August 2022. Only one research stay was executed in this period. Two research stays are planned for the last quarter of 2022. 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 compatibility with changes made at ECMWF for the single precision option, improvement of mass conservation and bit reproducibility on different platforms was ensured and some modifications were proposed. The compatibility of VFE with reformulation of NH system as a departure from hydrostatic system started to be examined.

The topic is ONGOING.

Executed efforts: 0.5 PM of local work

Contributors: Petra Smolíková

Deliverables: New routines for CY49 at GIT repository in Toulouse.

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.

Contributors: none

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 in the last year 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: The necessity of including the 3D processes like horizontal wind shear and advection to improve the representation of turbulence kinetic energy (TKE) and of turbulence total energy (TTE) in runs with kilometric horizontal resolution was indicated by recently published research. It is as well being recognized by ACCORD Work Plan. In the frame of this topic the implementation of horizontal features of the turbulence scheme TOUCANS was started. In the proposed solution horizontal shear effects were parametrized using three different approaches and were included in the prognostic equations for TKE and TTE. The formulation is based on the calculation of horizontal derivatives of the two wind components in which we benefit from the SLHD framework. The three approaches differ in the calculation of the horizontal turbulence length scale (HTLS) which is either constant and proportional to the horizontal resolution (Δx), or is variable and calculated from the velocity and time scales which are further parametrized. One of the issues is the necessity of numerical protection of zonal and meridional wind variances against zero values, which may lead to very high values of HTLS. The way how this protection is implemented makes the difference between the second and the third approach.

The effect of different HTLS calculations was compared on a test case of 1st July 2015, 00 UTC, run in the cascade of resolutions (4km, 2km, 1km) for 36 hours on the domain of Central Europe.

The impact of the quasi-3D turbulence scheme at coarser horizontal resolution (Δx=2km and Δx=4km) is almost negligible, while the performance of constant HTLS worsens as Δx increases (not shown). It is very encouraging to see that there were no problems with numerical instability with any of the three HTLS options we used. The analysis of spectral norms revealed their gradual development within the first few hours of the forecast and that there are no significant differences between 1D and quasi-3D experiments until the intensity of turbulence reaches its maximum, i.e., until early afternoon. The Horizontal Shear Production (HSP) values obtained with the constant length scale are too high for the north-facing slope location and even comparable with the Vertical Shear Production (VSP; Figure 1, blue color). Contrary, when variable HTLS is employed, the values become comparable. The variable HTLS options show pronounced daily variability, with maxima near the sunrise and noon (Figure 1, red and green colors). Finally, the TKE values are slightly higher with the variable HTLS formulations (not shown).

Additionally to the main code, an adaptation was made to have diagnostics of standard TKE and TTE budget terms (1D scheme), as well as the horizontal shear (HSP) and HTLS.

The analysis of vertical profiles of TKE reveals that turbulence intensity is higher throughout the model column for both valley-floor and north-facing slope locations than for the 1D scheme (Figure 2a,c). Obviously, this is a result of strong HSP near the surface (Figure 2b,d). The third approach to HTLS, which allows stronger horizontal mixing, is also able to produce secondary and tertiary maxima in the middle and upper troposphere. The reality of the latter should be a subject of further research as it could provide potential benefit for simulation of the jet stream related turbulence, as well as for lateral mixing at the edges of atmospheric fronts.

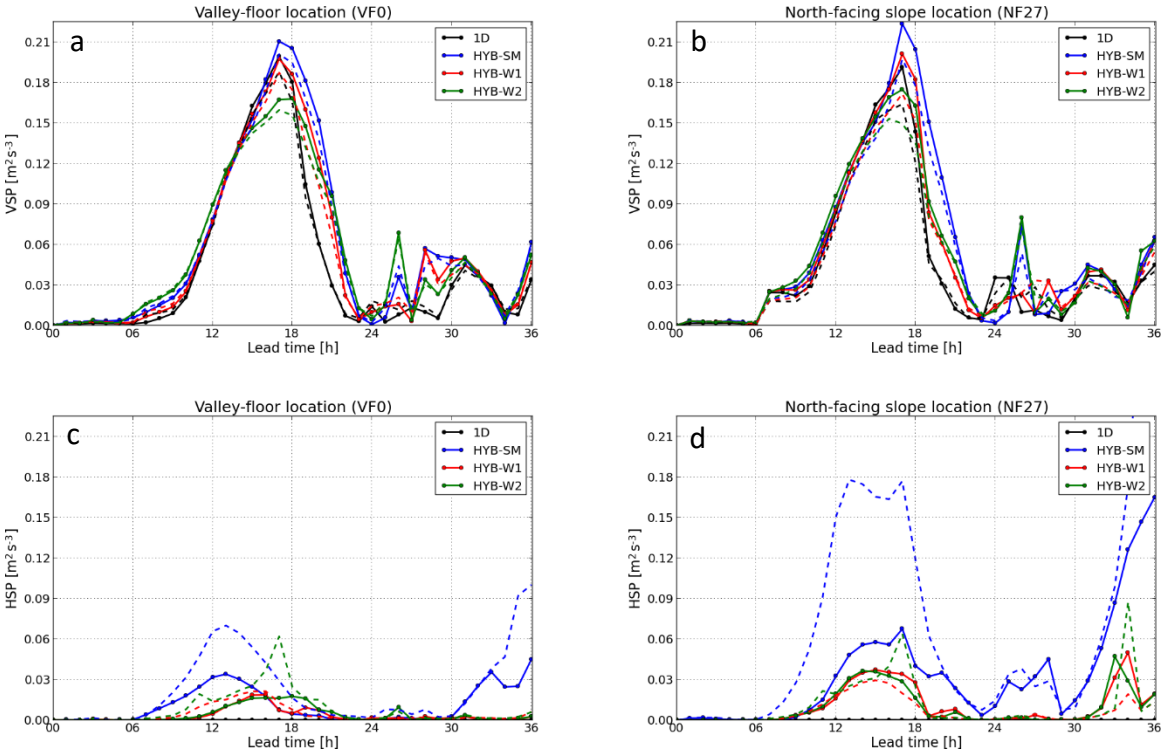

Figure 1: Timeseries of vertical shear production (VSP) and horizontal shear production (HSP) for valley-floor and north-facing slope location near Innsbruck, Austria, starting from 00 UTC on 1st of July 2015. 1D - 1D scheme, HYB-SM - quasi-3D scheme with constant HTLS, HYB-W1 - quasi-3D scheme with the second approach, and HYB-W2 - quasi-3D scheme with the third approach to HTLS. Full lines denote values from the nearest grid point, while dashed lines denote the mean value of 9 nearest grid points (Δx=1 km).

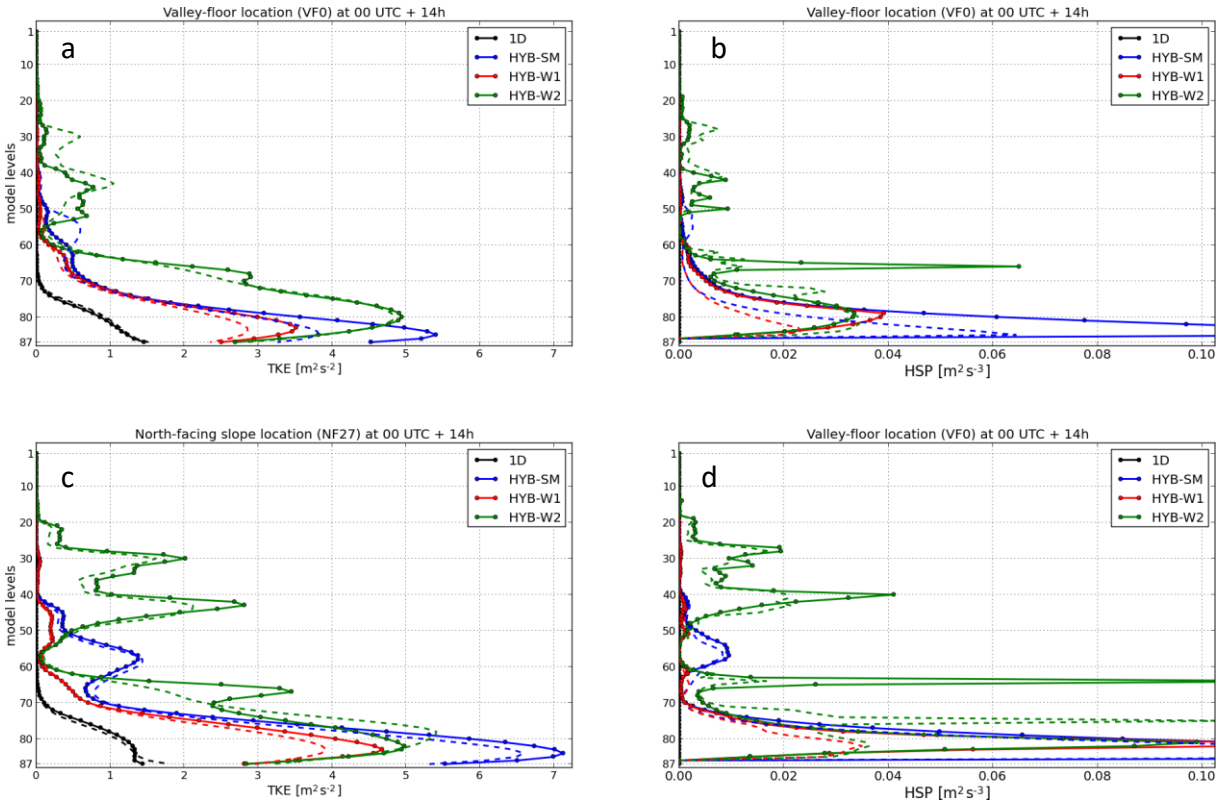

Figure 2: Vertical profile of horizontal shear production (HSP) and turbulence kinetic energy (TKE) for valley-floor and north facing slope location near Innsbruck, Austria, at 14 UTC on 1st of July 2015. 1D - 1D scheme, HYB-SM - quasi-3D scheme with constant HTLS, HYB-W1 - quasi-3D scheme with the second approach, and HYB-W2 - quasi-3D scheme with the third approach to HTLS. Full lines denote values from the nearest grid point, while dashed lines denote the mean value of 9 nearest grid points (Δx=1 km).

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

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

Documentation: the report from the stay published on the LACE web pages

Task 3. Time scheme

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

Description and objectives: One of the possible ways to attack this subject is a direct inclusion of the tangent-linear approximated model in the semi-implicit time scheme. The stabilising effect of such method was identified at ECMWF for the hydrostatic IFS by Filip Váňa, and the

potential of the new design of SI scheme has been exploited in low spatial resolution (corresponding to usual values in global applications). The most interesting point is the incorporation of orography and real vertical profiles into the linear model, while in the existing reference state for linearization no orography and only constant vertical profiles are present. The consequence of this new design of SI scheme would be no need of the spectral space representation of model variables and of transformations between spectral and grid-point spaces once the horizontal derivatives are calculated in a local way (for example through finite differences). The crucial point is here the iterative method used to solve the Helmholtz problem and its convergence behaviour in higher spatial resolutions (with steeper slopes). There are other less ambitious ways how the vertical profile of the reference state could be incorporated in the semi-implicit scheme which may be also investigated.

Status: **The topic is PENDING.**

Executed efforts: none

Documentation: none

Subject: 3.2 The trajectory search in the SL advection scheme

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 could be used as well regularly every Nth time step (N>1) to better balance the cost/stability properties of the whole scheme. Implementation of such choice would require careful allocation of corresponding buffers and thorough handling of the data flow between consequent time steps treated in a different way.

Status: **The topic is PENDING.**

Executed efforts: none, the research stay of Alexandra Craciun is planned for November 2022

Documentation: none

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

Documentation: 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.** Its realization is connected to the procurement of the new HPC in Croatia, since new application being run in higher horizontal resolution on the new HPC is foreseen to create the LBC files needed for the dynamical adaptation.

Executed efforts: none

Documentation: 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

Documentation: 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.

It seems that experiments on comparably large LAM domain were not run in the whole ACCORD consortium so far. In order to start experiments paving the way to NWP on hectometric resolutions, technical knowledge must be built first, including modifications of the model code and tools necessary for climate files generation, and for handling of huge FA files. Hence, the preparation of such experiments demands more workforce than is usual for increasing the model resolution.

The topic is ONGOING.

Contributors: Ján Mašek (CHMI), Petra Smolíková (CHMI)

Executed efforts: 1 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

Documentation: 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

Documentation: 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

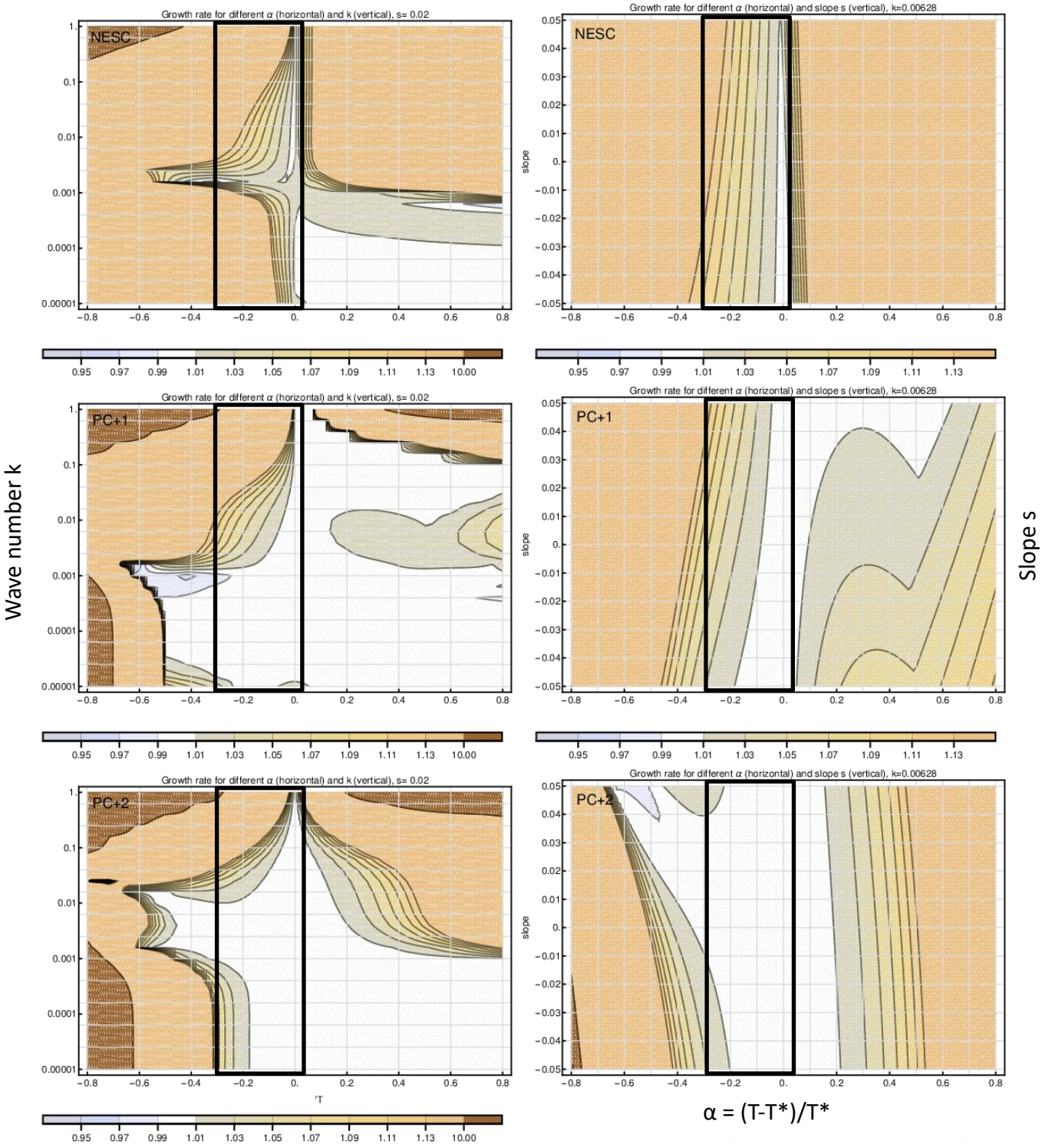

Figure 3: The analytic growth rate as a function of the nonlinearity parameter α and the horizontal wave number k (left column) or the constant slope s (right column). The other parameters are Δt=100s, T=300K, s=0.2 for the left column and k=0.00628/m for the right column. Blue or white colors mean stability of the given time scheme (NESC for the top row, PC with 1 iteration for the middle row and PC with two iterations for the bottom row), while orange or brown colors mean strong instability. The black rectangles indicate the position of the real atmosphere temperatures values, i.e. the area of the main interest.*

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 was prepared and submitted. The revisions are being undertaken after the review was finished. The main contributor Jozef Vivoda left SHMI (and RC LACE) for his new position in the ECMWF project DestinE. Hence, he will continue the work on the topic under the frame of ECMWF and we are prepared to further collaborate with him.

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 system with control parameters (as proposed when NH system is reformulated as a departure from HPE) in the presence of constant slope orography. 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: Jozef Vivoda (SHMI), Petra Smolíková (CHMI), Nika Kastelac (ARSO)

Executed efforts: 8 PM of local work

Documentation: a manuscript of the paper submitted to MWR, thesis about stability analysis with orography (in preparation)

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

Documentation: 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: **The topic is PENDING.**

Contributors: Gabriel Stachura, Petra Smolíková

Executed efforts: none, research stay of Gabriel Stachura at CHMI is planned for October 2022

Documentation: none

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

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 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 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: The topic is PENDING.

Executed efforts: none

Documentation: none

2. Documents and publications

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.

One report is being published on the RC LACE web pages:

Mario Hrastinski, *Implementation of the quasi-3D turbulence scheme within the ALARO Canonical Model Configuration*, 11pp.

3. Activities of management, coordination and communication

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

Planned events:

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) **High resolution runs workshop,** KNMI, DeBilt, Netherlands, December 2022 – participation of AL

4. LACE supported stays

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

1) Tuning and redesign of the horizontal diffusion depending on the scale – Mario Hrastinski (DHMZ), 1 PM in Prague

Two research stays are planned for the last part of 2022:

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 almost one half of the work we planned for the whole year. One research stay was executed in the length of 1PM. Two more research stays are planned for the last quarter of the year (highlighted in 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	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	0	1/0
	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	1	0	-
	4.2	Upper boundary condition	1	0	-
	4.3	Experiments in very high resolution	1	0.5	-
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	8	2/0

7. Coupling strategy	7.1	The impact of higher coupling frequency	2	0	-
	7.2	Frame approach in the LBC files	2	0	1/0
	7.3	The impact of higher truncation in LBC files	1	0	-
	7.4	Preparation of new LBC files from IFS	1	0	
Total manpower			**27**	**12**	**5/1**