Working Area Physics

Progress Report

Prepared by:	Physics Area Leader Mario Hrastinski (with inputs from Bogdan Bochenek)
Period:	1.1-31.12.2023.
Date:	23 February 2024

1 General Remarks

The intention is to foster thematical collaboration across ACCORD and across CSC teams, in the area of Physics pamaretrizations. Besides the ongoing development plans in the three CSCs, we intend to organize scientific exchanges (ideas, results, experiences, shared reporting) and an increased topical-wise animation (in the form of regular videomeetings, or a common workshop). On the shorter term, we can learn and be inspired from each other's work on the same parameterizations due to the new set-up of the RWP. On the (very) long term, there can be a natural tendency of parameterization convergence due to the increasing resolution.

2 Progress summary

Action/Subject: Turbulence & shallow convection (PH1)

Description and objectives:

Shallow convection schemes will ultimately be become obsolete and the turbulence schemes of the different CSCs mainly differ in their description of the large eddy's that will ultimately become resolved. A substantial part of the foreseen work on turbulence and convection is related to (very) high resolution runs and the grey zone.

Work (for the shorter term or a bit longer) on more pragmatic adaptation for the turbulence and shallow convection for running the CSC at 500 m or less by modifying mixing length and a more scale aware mass flux for shallow convection. Note that a scale-aware convection scheme might already be beneficial at current operational resolutions (between approx. 500 m and 2.5 km). Further, it emerges that the 3D effects of turbulence will have to be included (at least partly).

About the path towards 3D effects in turbulence, hereafter we recall the outcomes of the side meeting discussion at the 2022 ASW:

* the short/mid-term plans seem clear: implement and validate quasi-3D formulations, study the Goger etal. approach (in mountaineous areas), study the Moeng etal. approach (for strong convection clouds)

* towards "full 3D turbulence" (longer term):

- focus on what observations can teach us and what other have already done, make bibliography survey on what other academics have done regarding scale analysis

- full 3D turbulence requires to compute the horizontal divergence of horizontal fluxes, and it is important to first understand which of these terms really matter (cf scale analysis outcome)

- from the code point of view, we probably have all the relevant infrastructure for 3D turbulence, or we know how to code what's missing

- addressing the 3D effects of turbulence with SLHD (PH1.3).

ALARO: Developments of the TOUCANS turbulence scheme will continue with priorities in three main directions: i) finalization of the baseline version of the TKE-based mixing length formulation and its further upgrade (PH1.1), ii) revision of TOMs parameterization (PH1.2) and iii) addressing the 3D turbulence efects (PH1.3 - ALARO specific development and PH1.8 - common work with other CSCs).

Contributors, efforts: R. Brožková (Cz) 0.75 PM, M. Hrastinski (Cr) 2.5 PM, J. Mašek (Cz) 0.5 PM and P. Smerkol (Si) 7.0 PM; TOTAL: **10.75 PM**

Planned timeframe:

Planned deliverable: code modification, documentation updates

Sub-action: Turbulence length scale computation

Contributors: M. Hrastinski (Cr) 2.5 PM and J. Mašek (Cz) 0.5 PM

Efforts: 3.0 PM

Documentation, deliverable: stay report and code

Status/description: ONGOING

Following the conclusions of TOUCANS brainstorming and based on related developments during the previous year (Hrastinski, 2022), Mario Hrastinski continued his work towards finalising the TKE-based turbulence length scale (TLS) in TOUCANS (Hrastinski, 2023). After adjusting the mixing near the PBL top (L_{BLT}) based on the increment of moist entropy potential temperature ($\Delta\theta_s$) within 1.5 times the depth of the PBL (H_{PBL}), the final and missing piece of the formulation was added in the form of the upper-air lower limit (L_{UTLS}), with a linear transition between the two (L_{TRANS}). The introduction of L_{UTLS}, which is associated with turbulence in the free atmosphere, i.e., near the jet stream, aims to preserve the framework given by the reference formulation and introduce a clear separation from turbulence within the boundary layer. We highlight situations with stable stratification in the surface layer and presence of high-altitude jet stream as particularly problematic in this context. Extending the weak mixing near the PBL top toward higher altitudes would suffocate the jet stream-related turbulence.

The height-dependent combination of L_{BLT}, L_{TRANS} and L_{UTLS}, denoted in Hrastinski (2023) as L_{MIN}, represents the lower limit of L_{TKE}, which is the TLS based on vertical displacements of air parcels following Rodier et al. (2017). Finally, within the surface layer of the PBL, L_{TKE} blends with the near wall scale κz. This blending is height-dependent, while a smooth transition between these two scales is achieved by utilizing the third-order polynomial. The schematic overview of the new TLS formulation is given in Fig. 1, while its configuration is supported by the results of related LES diagnostics.

The new TLS formulation is getting validated in different weather situations, including convection and inversion. The first results suggest a considerable improvement in forecasting the inversion-related low cloudiness and temperature profiles. However, some improvement is also seen in precipitation patterns during the convection. Additionally, a more dynamic nature of the TLS new formulation is confirmed in a case with overestimated low cloudiness, wherein it was reduced compared to the reference formulation. Extending the number of above cases always showed a neutral to slightly positive signal. Further validation and fine-tuning of formulation-related parameters are needed. The related publication and technical documentation are in preparation, i.e., the "how to use" manual.

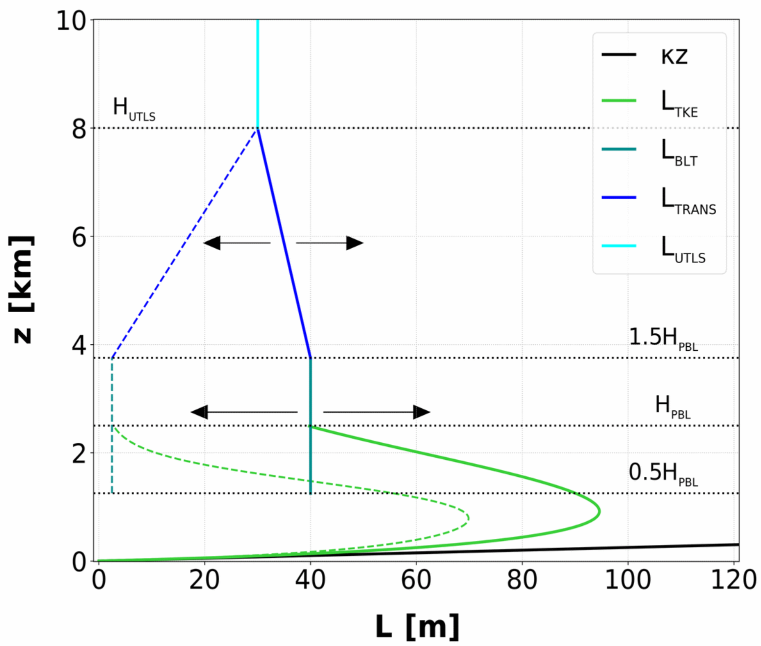

Fig. 1: Schematic representation of unified and regime-dependent turbulence length scale formulation based on prognostic TKE, shear and buoyancy. The contents of the legend, i.e., TLSs, are explained above in the text.

During the research stay at CHMI, the related code was finalized and merged with a local **CY43t2ag_op1mxl** branch, containing the following developments: i) H_{PBL} (two new methods were introduced) and $\Delta\theta_s$ computations, ii) a mix of local and non-local flux Richardson number, iii) reduction of the upper-air asymptotic value of the reference TLS formulation based on $\Delta\theta_s$, iv) untruncated F_ε in the computation of K_{ek} and v) correction of "tilded" turbulence energies related to more stable and iterative solver following Mašek et al.

(2022). Jan Mašek is currently phasing the code to CY46T1, aiming to use the above formulation within the new version of RC-LACE ensemble system A-LAEF and for local testing at CHMI.

Sub-action: Third-Order Moments (TOMs)

Contributors: P. Smerkol (Si) 7.0 PM

Efforts: 7.0 PM

Documentation, deliverable: short report and documentation

Status/description: ONGOING

Peter Smerkol contidued his work on stabilizing the TOMs solver (ACDIFV3 subroutine), following the plan from the TOUCANS brainstorming held in 2022. Therein, it was discussed that the problem mentioned might be caused by: i) use of the virtual instead of entropy potential temperature in the solver, ii) additional temporal term, which is unclear, iii) usage of solver on the moist case, with non-neutral stratification, which is the most complex one, and iv) questionable assumptions used in the derivation of solver equations.

The focus in 2023 was on revision of the theory, focusing on TOMs closure assumptions in Cheng et al. (2002), which is the basis for the TOUCANS scheme, starting from Canuto (1992) as the most general approach. Some inconsistencies were found. Especially in the closure of third order pressure-velocity gradient terms, where it seems that only fully convective cases without any mean shear effects were considered in the derivations. This has to be discussed further. In parallel, the related documentation is being written.

Sub-action: Towards the 3D turbulence (cf. Dynamics & coupling report)

Contributors: M. Hrastinski (Cr) and P. Smolíková (Cz)

Efforts: 0.0 PM

Documentation, deliverable: stay report (previous)

Status/description: ONGOING

Although being a part of the PH1 package in ACCORD RWP, this topic is reported in “Dynamics and coupling” area of RC-LACE. It was initiated in the context of the (sub-)kilometer ALARO-CMC optimization and link to the Semi-Lagrangian Horizontal Diffusion.

Sub-action: Wind gusts estimation based on prognostic TKE

Contributors: R. Brožková (Cz) 0.75 PM

Efforts: 0.75 PM

Documentation, deliverable: short report

Status/description: ONGOING

Although being reported within the COM package of the ACCORD RWP, this topic is mentioned here due to its link with turbulence parameterization. Given the quite windy winter, forecasters at CHMI again pointed to the overestimation of wind gusts. Therefore, the local NWP team utilized the e-suite to introduce the calculation of gusts based on TKE. They started with values of related parameters close to those used by ARPEGE and AROME, i.e., HTKERAF = 20 m above the ground and the factor FACRAF~4. The comparison with measurements from Czech stations suggested setting FACRAF=3.6. An example of a single mountain station is shown in Fig. 2.

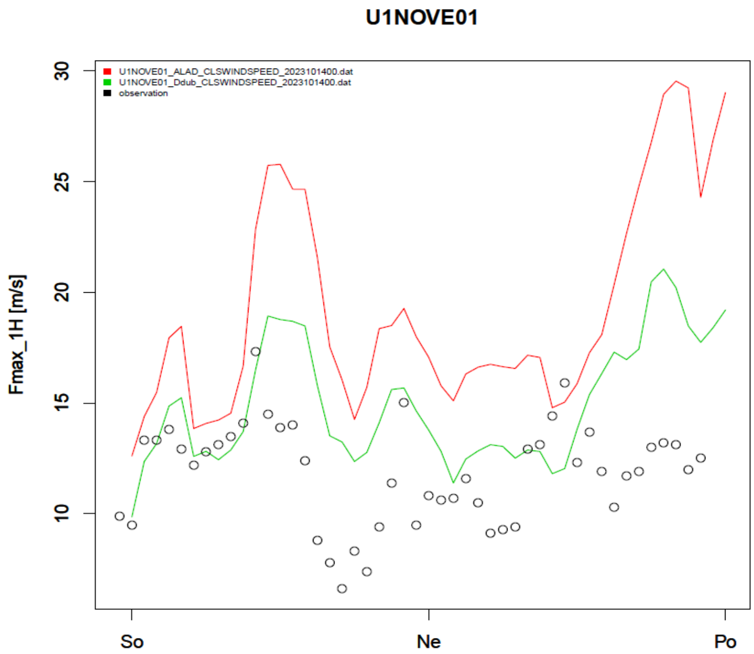

Fig. 2: The comparsion of measured wind gusts for a mountains stations (black circles) with model diagnostics obtained from: i) operational configuration based on friction velocity (red) and ii) e-suite based on prognostic TKE (green).

Additionally, the work on ALARO single precision version continued during stay of Oldřich Spaniel in Prague (reported to SY package). Fixes for TOUCANS were delivered, making single-precision TKE scheme working on CY46T1. TTE scheme has to be tested yet. For this we wanted to move on CY48T3 or CY49, where recent turbulent developments are phased, but there are still some more fundamental problems with single-precision there. Plus there is a problem with VFE scheme and 87 levels, unrelated to cycle.

Action/Subject: Radiation (PH2)

Description and objectives:

The radiation scheme is well known as the most expensive component of the model physics. The related developments are reported in other packages of the ACCORD-RWP, e.g., PH6, SPTR and SY1. Currently, in LACE, only the ACRANEB2 developments are being conducted.

The focus is put on interfacing of ACRANEB2 radiation scheme with near real time aerosols, plus externalization of cloud effective radii. These points are addressed within workpackage PH6. Apart from that, minor improvements of ACRANEB2 scheme are planned: interfacing and testing of single precision version in 3D model, inclusion of CFC-11 and CFC-12 in CO2+ composite, impact of clouds on the broadband surface albedo. Future revision of gaseous transmissions is possible. There is currently no idea how to accommodate 3D effects in ACRANEB2. GPU refactoring issues will be solved during preparation of APL_ALARO. Plugging of ecRad in APL_ALARO is also considered.
At the side meeting of the ACCORD ASW 2022 on 3D effects in physics, the following workplan had been outlined:

- evaluate a poor man's solution (TICA) for taking into account some 3D effects, however we could perhaps aim for a more ambitious and valuable plan (see next bullets)

- develop a coarse grid approach with SPARTACUS, the 3D solver that comes with ECRAD: (1) study the IFS code solution and draft specs for LAM; (2) implement the call to SPARTACUS in LAM; (3) use fine grid fields for cloud overlap, effective cloud edge length, cloud optical saturation

- first steps should be to form a task team to further discuss this work plan, evaluate the manpower needs for its realization and start assessing its possible staffing (it was noted that ACCORD might need an ECRAD expert of its own)

Contributors, efforts: NONE, **0 PM**

Planned timeframe:

Planned deliverable: NONE

Status/description: PENDING

Although there were no direct contributions by LACE developers to the PH2 package of the ACCORD RWP in 2023, there were several related developments within other packages. Among these, the following stand out: i) the first tests of single precision ACRANEB2 with ALARO-0 (SY1 package), ii) ALARO refactoring (radiation scheme included; SPTR package), and iii) CAR developments (PH6 package).

Action/Subject: Clouds-precipitation microphysics (PH3)

Description and objectives:

Currently, the LACE developments within this package are conducted under the ALARO-CMC. The focus is on the improvement of autoconversion, collection, evaporation and melting processes, all of them using prognostic graupel. Comparisons are made with solutions in other microphysics packages: ICE3, WSM6, Thomson, COSMO, and UM. The impact of improvements in vertical geometry will be evaluated. The inclusion of n.r.t. aerosols in APLMPHYS is considered.

Contributors, efforts: R. Brožková (Cz) 3.5, D. Němec (Cz) 8.25 PM and B. Toth (Hu) 0.25 PM; TOTAL: **12.00 PM**

Planned timeframe:

Planned deliverable: code modification, short report and namelist

Sub-action: Tuning and testing new options in ALARO three-ice microphysics

Contributors: R. Brožková (Cz) 3.5 PM and D. Němec (Cz) 2.25 PM

Efforts: 4.75 PM

Documentation, deliverable: short report and namelist

Status/description: FINISHED

The three-ice microphysics scheme, with Lopez evaporation, was tuned to make it suitable for operational use by alleviating its deficiencies. The focus was on reducing the cold temperature bias and STDE of wind speed/direction due to increased stability in the boundary layer while keeping the benefit of reduced precipitation and short-wave radiation biases in autumn.

To achieve that, a reduction of evaporation per precipitating hydrometer was introduced (REVASX[RSG]). At CHMI, it is used only for rain. Besides, autoconversion coefficients for rain were adjusted. In radiation, the correlation depth of clouds evinces a more distinct yearly cycle closer to the findings of Oreopoulos (2022), and the vertical profile of critical relative humidity in radiation requires higher relative humidity for condensation (increased value of HUCREDRA).

As a result of the above changes, the precipitation bias during a 22-day autumn period is considerably reduced (Fig. 3), while the temperature bias is unchanged. These adjustments are currently tested in a parallel suite at CHMI, proving the reduced bias of precipitation.

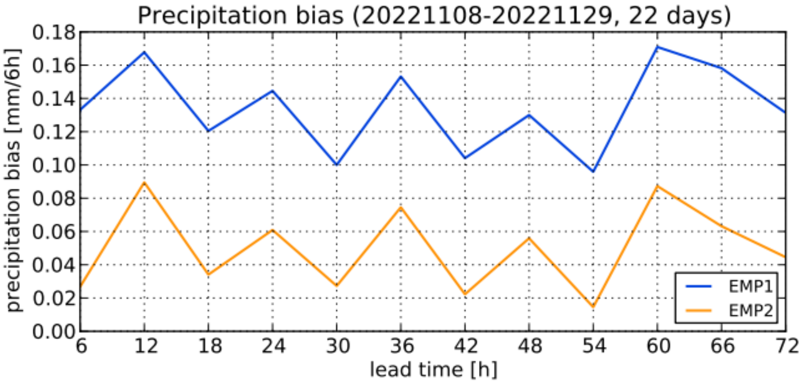

Fig. 3: The bias of precipitation during the period 8-29 November 2022 for: i) operational configuration at CHMI (blue) and ii) parallel suite with tuned microphysics scheme (orange).

Sub-action: Development of two-moment ALARO microphysics scheme with aerosols

Contributors: D. Němec (Cz) 2.75 PM

Efforts: 2.75 PM

Documentation, deliverable: short report and code modification

Status/description: ONGOING

The first steps towards a two-moment scheme with aerosols in ALARO have been made. In the first stage, the use of CAMS aerosol climatology is intended. So far, the activation scheme for cloud droplets was introduced using a look-up table created at the zeroth time-step. Its output is the number concentration of cloud droplets influencing autoconversion rates. The autoconversion formula was changed from Sundqvist to Khairoutdinov and Kogan (2000) (hereafter KK2000). In addition, the equation for the rain-collecting cloud ice and cloud water follows KK2000.

The KK2000 parameterization was tested before without the activation scheme. However, it delivers too high mass fraction of liquid water in stratocumuli. The activation scheme compensates for this effect since the cloud droplet number concentration in stratocumuli is less allowing for more effective autoconversion.

Sub-action: Testing the subgrid statistical cloud scheme at HungaroMet Nonprofit Zrt.

Contributors: B. Toth 0.25 PM

Efforts: 0.25 PM

Documentation, deliverable: short report

Status/description: FINISHED

Based on previous tests of the new cloud parametrization, it was decided that further studies are needed on a longer summer period to investigate the impact on convection. Thus, the AROME-TEST (LOSIGMAS=.T., VSIGQSAT=0.02) was running in parallel to the operational AROME-HU forecasts (LOSIGMAS=.F.) from the end of June 2023 until mid-September. Similar to previous verification of parallel runs, some objective and subjective evaluations were carried out and the forecasters were also involved.

The most positive effect of the prognostic formulation (LOSIGMAS=.T.) was visible in the more accurate prediction of cloud dissipation, which improved the global radiation and the maximum temperature. Due to the more fragmented clouds, stronger radiation appeared in the test version, thus reducing the underestimation. A positive impact was seen also for the dewpoint and relative humidity in the nighttime. During the day, neutral effect or minimal deterioration occurred for several parameters. However, in clear and dry weather situations, the test gained advantage even in the daytime. During this convective period, the precipitation structure was more discrete and isolated. Thus, the number of precipitation objects became more accurate in the AROME-TEST (based on the SAL). As a result of higher surface incoming radiation, more accelerated cumulus cloud formation started, which was often accompanied by the formation of stronger, convective cells (Fig. 4). According to the forecasters, in many cases, this was closer to measurements, but sometimes led to overestimation or false precipitation objects.

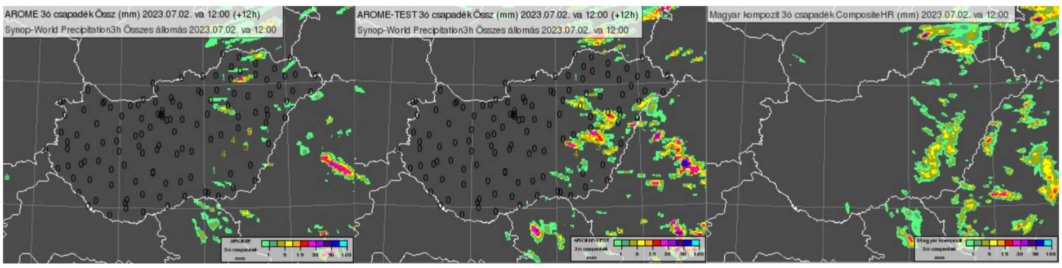

Fig. 4: 3-hour precipitation sum (in mm) based on 00 UTC + 12h-forecasts of AROME (left) and AROME-TEST (middle), Hungarian radar measurements (right) and SYNOP observations (marked with numbers in the first two panels) on 2 July 2023.

Overall, a variable performance wa achieved in this convective weather period, but the positive results in the case of clouds, radiation and temperature extremes. Furthermore, the reduction of night-time inaccuracies, allowed the operational implementation of prognostic scheme on 06 November 2023.

During Q1 and Q2, David Nemec prepared the proposal for improved autoconversion and evaporation processes, and also participated in their implementation and validation. Total invested time was 3.25 PM.

Action/Subject: Common 1D MUSC framework for parametrization validation (PH4)

Description and objectives:

Maintain and regularly upgrade a “common MUSC” 1D testing environment for Arome-France and Harmonie-Arome, for the evaluation of physics parametrizations against Cloudnet and LES data and idealized experiments.

In 2018/2019 a new version of MUSC has been developed at Met Eireann, which is much more user friendly. However, no special reference cases are part of this system, so the old test cases have to be added (GABLS-1, GABLS4, ARM-Cu, ASTEX and a Cabauw fog case). Desired new cases include e.g. a case with light recipitation (RICO), dry convection, and an idealized case for mixed-phase clouds.

In 2021, a beta version of the common (between the 3 CSC) MUSC version based on cy46t1 have been created during the Working Week in 2021 and validated at least for some cases for the 3CSC without SURFEX, however some works needs to be done for ALARO and SURFEX. The visualization tool EMS developped by R. Roerhig is now available. A continuation effort shoud be done in 2023 to increase the number of available "ideal" cases in order to have a diversity of meteorological siutation to evaluate, compare all the parametrizations available accross the CSC and ARPEGE. Therefore a training and/or working days can be organized may be every two years or for a new MUSC version based on a new cycle.

Contributors, efforts: A. Šljivić (Cr) 0.75 PM; Total: **0.75 PM**

Planned timeframe:

Planned deliverable: code contribution and stay report

Status/description: PENDING

Across the ACCORD community, different surface scheme options are available. AROME and HARMONIE-AROME CMCs utilize the SURFEX scheme, while ALARO CMC uses the old ISBA scheme. Having a simplified surface scheme would introduce the possibility of running different CMCs with the same surface settings. Further, such a scheme may be used for running a single-column model (MUSC), for which surface input fields do not need to be very detailed.

Ana Šljivić has continued the development of a simplified surface scheme GROUND_SPISBA, which started during her stay at Meteo France in 2022. The first version of the scheme was prepared in Q1 of 2023. After having a stable simulation and meaningful results (at first validation), the next step would be the implementation to APL_AROME and making more thorough validation.

Action/Subject: Model Output Postprocessing Parameters (PH5)

Description and objectives:

There is an increasing need for new postprocessing parameters out of the NWP systems for many applications such as aeronautics, green energy sector, automatic forecasting and for various end-users. This need is reflected in the ongoing work of many NMSs in ACCORD. In this WP, we address the work on the model output, as produced mostly from the executables available from compilation (ie MASTERODB). The activities on postprocessing are coordinated within this package in order to avoid possible duplication of work. In 2021, an inquiry was launched in order to update the list of diagnostic and output fields planned or under consideration by the local teams. The goal then also was to understand whether these model outputs could/should be considered for computation during the model runtime (if they require specific model fields) or whether they could/should be part of an offline, downstream post-processing. Only the first case clearly belongs to the ACCORD RWP matters (common codes).

As an outcome of the 2021 inquiry (aka PH5-questionnaire), the model output fields have been grouped into four categories for which we intend, at ACCORD level, to build more synergy across teams. Various needs for postprocessing fields (for traffic, energy or tourist/sport sectors) can be assigned to a task depending on the category of the required output. The intention is to organize dedicated meetings per category, so that the teams involved in each can exchange about their plans, and transversal collaboration per thematic can be encouraged. Another aim of the WP PH5 is to coordinate the work done on the implementation of the selected parameters into the common code for all three CSCs, and to implement, tune and validate these parameters. The new postprocessing parameters need to be validated (related to MQA) and for that new data types might be needed (DA3-DA4). Specific postprocessing related to ensemble forecasts is addressed in EPS packages, the same for DA etc.

Contributors, efforts: D. Němec (Cz) 1.0 PM and A. Simon (Sk) 4.25 PM; TOTAL: **5.25 PM**

Planned timeframe:

Planned deliverable: code modification, documentation updates

Status/description: ONGOING

The Fullpos implementation of new ALARO deep convection outputs was performed to local CY46T1 at CHMI by David Němec. These products include: storm-relative and updraft helicity, updraft and downdraft track, and simultaneous calculation of MUCAPE and MLCAPE. At SHMI, André Simon worked on phasing the parameterization of wet snow and ice accretion on power lines to CY49T0 through Github, which was accepted and is now a part of the CY49T1 (ARPEGE). However, different versions of the scheme exist on various cycles, i.e., CY43T2, CY46T1 and CY48T3. Further adaptations and phasing (partially already done) are needed and will take place in 2024.

Action/Subject: Study the cloud/aerosol/radiation (CAR) interactions (PH6)

Description and objectives:

Basic decision is to use CAMS n.r.t. aerosol mass mixing ratios (MMRs), and to provide infrastructure enabling its exploitation in all ACCORD CMCs. The design should be general enough in order to make possible future use of alternative aerosol data (e.g. from MOCAGE). Usage of CAMS aerosol MMRs via traditional monthly climate files will be ensured, as well as backward compatibility using aerosol optical depth (AOD550) climatology as input. PH6 aims at: 1) Preparation and transfer of aerosol input to the forecast model 2) Ensuring consistent code structures, interfaces and namelist definitions in the forecast model, available for specific radiation and cloud microphysics parametrizations 3) Providing utilities for use in data transfer, namelist generation and testing.

Contributors, efforts: J. Mašek (CZ) 0.75 PM, P. Sekuła (Pl) 6.25 PM and A. Šljivić (Cr) 2.0 PM; TOTAL: **9.0 PM**

Planned timeframe:

Planned deliverable: code modification, stay reports

Status/description: ONGOING

Work on aerosol code continued in CY46T1-bf07 during the stays of Ana Šljivić and Piotr Sekula in Prague. The calculation of cloud liquid and ice effective radii was externalized from ACRANEB2 to enable the use of their values from microphysics (currently, this is possible only in AROME). The results were not reproducible with the old way, but it was concluded that differences are minor and can be neglected. During tests, it was realized that cloud fraction in AROME microphysics and radiation is not the same, raising the question of relevant in-cloud liquid/ice water content for diagnostics of cloud particle size for radiation.

Dataflow of 2D climatological (monthly Tegen – 4 aerosol types or monthly CAMS MMRs – 11 aerosol types) and 3D near real-time aerosols was finalized and tested. There is a pending question on redistribution of vertically integrated mass of climatological aerosols to their 3D mass mixing ratios. Inspection of 3D CAMS data suggests that exponential distribution should be generalized to a gamma distribution to be able to capture the peak seen in the PBL. Most of the code development was merged by Piotr Sekula on CY46T1 and further consolidated by Ján Mašek.

Action/Subject: Interface issues between the surface and the atmosphere (PH7)

Description and objectives:

This WP deals with interaction issues between the surface and the atmosphere and focuses especially on a few topics including stable boundary layers, ALARO-SURFEX coupling, the role of the lowest model level and surface properties, currently TEB, included in the atmospheric parameterizations.

The stable boundary layer and our inability to properly model it, with consequences for near-surface essential variables like e.g. T2m, has been a long standing problem. This subject was brought up in a side meeting of the 2022 All Staff Workshop and a summary of the discussion and suggested ways forward is given via this link. In this WP we will first look into the items additional term to scalar-flux formulations and learn from relevant observations via our academic contacts.

The coupling of ALARO to SURFEX includes a number of issues, some are directly SURFEX related and will be covered by tasks in SU3 and SU6 while some are dedicated to the interface between ALARO and SURFEX codes and will be covered by tasks in this WP.

With an increasing number of atmospheric vertical levels we tend to push the lowest model level closer to the surface. For stable boundary layers (BLs) this is often beneficial since they are characterised by thin BLs, however, for neutral and unstable BLs the enforced homogeneous atmospheric conditions close to the surface have no support in reality. Tasks in this WP will be dedicated to investigate the consequences for atmospheric-surface interactions of very low lowest model levels and investigate alternative approaches.

Research and development are published where very tall buildings (O100m) present in the TEB tile are explicitly handled in the atmospheric code of the Meso-NH model, including parameterizations of fluxes between model levels and the buildings. This research and development is now being transferred to the AROME-SURFEX context which will change the until now strict interface between SURFEX and AROME/ALARO at the lowest model level.

Contributors, efforts: R. Brožková (Cz) 0.5 PM, M. Ličar (Si) 3.5 PM, J. Mašek (Cz) 6.0 PM; TOTAL: **10.0 PM**

Planned timeframe:

Planned deliverable: code modification, short report

Sub-action: ALARO+SURFEX debugging and preparation of contribution for CY49T1

Contributors: M. Ličar (Si) 3.5 PM and J. Mašek (Cz) 4.0 PM

Efforts: 7.5 PM

Documentation, deliverable: short report and namelist

Status/description: ONGOING

Modset with fixes enabling to run ALARO with SURFEX, prepared in CY46T1, was phased to CY49T1. This implied move from SURFEX version 8.0+ to 8.1+. During the pull-request review, some modifications proposed by Patrick Samuelsson were done in order to make consistent with SURFEX design and with some options already existing in the SURFEX NWP branch. These include:

(1) Removal of key LARP_PN. Default SURFEX setting gives back the AROME choice. For ARPEGE and ALARO, vegetation thermic coefficients must be set via XUNIF_CV array during PGD step, and XTAU_ICE must be set during integration.

(2) Tree height scaled during runtime by array XSCALE_H_TREE. Original intention was to have the scaled tree height written in PGD file and taken consistently from there, but there were technical problems to achieve that.

Apart from various fixes, the contribution also contains several developments: i) consistent averaging of mechanical and thermal roughness lengths, ii) optional inclusion of orographic roughness length on the patch level, and iii) the possibility of ALARO screen level diagnostics done by ACTKECLS after SURFEX call.

The part related to CY49T1, including use of GitHub and DAVAI was reported to COM2. package of the ACCORD RWP. There was also a contribution from Radmila Brožková related to ALARO+SURFEX debugging reported to SU3 package of the ACCORD RWP. In parallel with above, Matjaž Ličar from ARSO was dealing with local technical implementation and debugging of ALARO+SURFEX on CY43T2 and with setting up cycling.

Sub-action: Hydrological budget and heat fluxes study

Contributors: J. Mašek (Cz) 1.0 PM

Efforts: 1.0 PM

Documentation, deliverable: short report

Status/description: ONGOING

This topic is related to CHMI's efforts in climate modelling. Two ALARO simulations of the past climate were compared, i.e., reanalysis run with surface data assimilation and upper air blending and evaluation run with freely evolving surface variables. The performance of the reanalysis run is similar to the ALARO NWP version. However, within the evaluation run, a cold bias of daily T2m (up to 1K) appears in spring and summer (Fig. 5). A basic check of the surface water budget was performed. It showed that while the total precipitation in both runs is similar, surface data assimilation removes part of soil water, reducing both evaporation and runoff in the reanalysis run. According to expectations, the long-term surface water budget in the evaluation run is balanced. The inspection of the surface energy budget is still in progress.

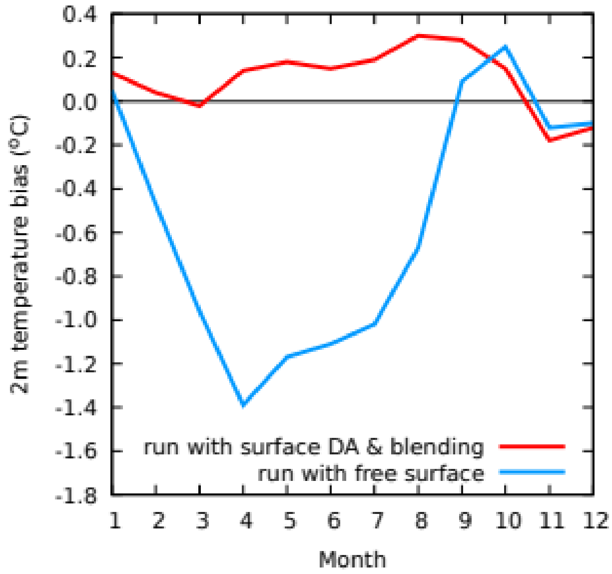

Fig. 5: The bias of mean daily temperature at 2 m averaged over Czech Republic in period 1995-2014.

Sub-action: Revising the impact of snow on the vegetation roughness length

Contributors: R. Brožková 0.5 PM and J. Mašek (Cz) 1.0 PM

Efforts: 1.5 PM

Documentation, deliverable: short report

Status/description: ONGOING

A problem with the overestimation of 10 m wind speed over forested areas with snow was identified at CHMI. It turned out that the current treatment of the vegetation roughness length (RL) with snow is not satisfactory as it averages between vegetative (1-2 m in the forest) and snow values (1 mm), using the snow fraction as weight. Thus, when the snow fraction approaches 1, the RL over the forest will approach 1 mm, which is unrealistic unless the snow depth reaches the height of trees. Reducing the RL proportionally to the ratio of snow height to characteristic obstacle height is proposed as a cure. The new treatment enters CY49T1 under key LZ0SNOWH on the ISBA side and LZ0SNOWH_ARP on the SURFEX side. More extensive testing is still needed.

Another snow-related issue was tackled following the changes in the surface assimilation at CHMI. The contribution is reported under SU1 package of the ACCORD RWP and is not accounted here. After switching to 3-h cycling, they stopped to relax the snow cover (reservoir of its water equivalent) to the climatology, despite not having the snow analysis. The relaxation, even if weak, led to snow cover underestimation (especially in the mountains). Since snow cover changed considerably, it brought attention to related impacts on RL (wind speed) and radiation (temperature). When the grid box is covered with snow only partially (also due to vegetation or rough terrain), a tuning constant is used to spread the snow more or less within the grid box. The radiative impact is quite dramatic. It can cause errors in screen level temperature of several degrees. A study was made on the impact of related WCRIN parameter, i.e., it was changed from WCRIN=4 to its default value WCRIN=10. It led to smaller surface covered by snow within the grid box and helped a lot to correct the cold temperature bias. A new WCRIN value was introduced to the current e-suite.

Action/Subject: On the interface of Physics with Dynamics (and time stepping) (PH8) (cf. Dynamics & coupling report)

Description and objectives:

This WP lists specific tasks that are at the interface between physics and dynamics, in terms of codes and of scientific interest.

1) Regarding the physics/dynamics interface, one scientific issue is that local sources and sinks of total water in the physics are automaticaly compensated by local sinks/sources of dry air. The reason is that total mass conservation is the law imposed by the continuity equation of the model even if the physics parametrisations create sources/sinks of total

water. Thus, the model does not conserve dry air.

Physics parametrisations are usually solved either at constant pressure or at constant volume. In the non-hydrostatic model, one has to account for the changes in pressure that happen due to physics parametrisations consistently with the choices made in the physics dynamics interface and the dynamics.

2) Attention is given to the relative roles of horizontal and vertical diffusion (turbulence) across scales. The horizontal diffusion will be re-designed and tuned depending on the scale aimed to in the high resolution experiments. The computation of the SLHD diffusion coefficient will be modified to become a function of the total flow deformation. The relation between the horizontal diffusion applied by the model dynamics (SLHD or conventional spectral horizontal diffusion) and the parametrized vertical diffusion will be studied for a range of resolutions. This re-assessment of SLHD and gridpoint-based dissipation also is in link with hyper-resolution model design.

3) For the sake of numerical cost, and with a view on hyper-resolution model design, it could be of interest to study time split solutions in which the dynamics tendencies would be

computed over a shorter time step than the physics (rather than compute all tendencies with a same, short time step). Time splitting per se will require specific work in some future, regarding its relevance on numerical stability and accuracy of solution. The task described in this WP is about studying the needed code design for enabling a time split facility in the common codes.

Contributors, efforts: M. Hrastinski (Cr), 0.0 PM

Planned timeframe:

Planned deliverable: code modification, stay report

Status/description: ONGOING

Although being a part of the PH packages in ACCORD RWP, this action/subject is reported in "Dynamics and coupling" area of RC-LACE. It was initiated in the context of tadapting the Semi-Lagrangian Horizontal Diffusion for (sub-)kilometer horizontal resolution.

Action/Subject: SURFEX: validation of existing options for NWP (SU3)

Description and objectives:

The main objective is to progress with better physics by exploring advanced SURFEX components, also not used before in ACCORD CSCs.

With respect to the nature tile, advanced physical components include the Diffusion Soil scheme (ISBA DIF), Explicit Snow scheme (ES) and Multi-Energy Balance (MEB) scheme. The DIF scheme also offers a number of hydrological options. Assessing the potential of the new options should be done in tight connection to the corresponding assimilation methods (SU1). In addition, options allowing prognostic LAI (A-gs) could provide better surface resistance and transpiration control and opens up the way for assimilation of LAI products (SU2).

Over the land, errors in forecasting low temperatures are related to wrong representation of the stable boundary and surface layer in NWP. Studies are planned, to better understand the problem and to move forward in its solution.

Over the sea tile, turbulent fluxes are calculated using different versions of ECUME scheme. Correct representation of surface fluxes over the sea in important for the simulation of large scale processes. Also, it is linked to the succesful forecasts of fog over the sea. The objective is to test the performance of difference formulations of the ECUME against available observations and to study its relation to the forecasting of fog.

Urban tile, which is described by TEB model, covers relatively small fractions, but is important for the local weather. It is especially important when the model resolution increases. TEB is implemented without data assimilation. Performance of TEB for different city types and different weather conditions needs validation against dedicated obesrvations, including measurement campaigns.

Inland water tile is represented by FLake. FLake is currently operational in the HARMONIE-AROME for MetCoOp. It is implemented without data assimilation, thereby monitoring of its performance is important.

Observations needed for the validation are partly provided by QA3, with tools like Monitor and HARP. However, they should be complimented by special observations: from measurement campigns, non-conventional near-surface observations, flux tower data, and satellite products. All parameterizations include parameters with some level of uncertainty. There are parameters in SURFEX which are a matter of tuning. Tuning may give a better performance of a certain ACCORD cycle release for a certain domain.

CSC details:

AROME: The 1D ocean mixing layer model CMO has been tested and implemented in some AROME configurations at Météo-France (Overseas). The intention is to further improve this coupling for tropical cyclone prediction. The 1D sea ice model GELATO will be tested in Arpege and also in experimental Arctic AROME.

ALARO: Scientifically consistent transition of ALARO-1 from directly called 2-level ISBA to SURFEX should be finalized, addressing also observed fibrillation issues. Goal is to have the necessary changes entering t-cycle (NWP SURFEX commit).

Contributors, efforts: R. Brožková (Cz) 1.0 PM, J. Mašek (Cz) 1.0 PM, S. Schneider (At) 1.50 PM and G. Stachura (Pl) 1.50 PM; TOTAL: **5.0 PM**

Planned timeframe:

Planned deliverable: code modification, documentation updates

Status/description: ONGOING

A significant effort (at CHMI) within this package was devoted to debugging ALARO with SURFEX and moving from SURFEX 8.0 to SURFEX 8.1. During the stay of Gabriel Stachura in Prague, ALARO with new SURFEX options was run technically. The diffuse scheme with 14 soil layers and the explicit snow scheme with 3 or 12 layers were tested. In NWP configuration, the force restore method with a 3-layer snow scheme is interesting, while for climate runs, the target is a diffuse scheme with 14 layers and a snow scheme with 12 layers. As no tool to transform the initial state from composite snow scheme to multi-layer snow scheme was found, technical tests were performed with snow initialized to a horizontally constant value. Therefore, in NWP configuration, multi-layer snow cannot be interpolated from ARPEGE, which still uses a single-layer D95 scheme. It will be necessary to copy multi-layer snow from guess. The situation in the climate configuration is simpler. Simulations can start from zero snow, and the snow cover is created from snow precipitation during several years of the spin-up period.

At Geosphere Austria, for the DEODE needs, Stefan Schneider was dealing with testing PGD and PREP to create initial conditions for high-resolution AROME with IFS. The outcome is not known at the time of this report writing.

Action/Subject: Assess/improve quality of surface characterization (SU5)

Description and objectives:

The main objective is to assess and improve quality of surface characterization.

The surface physiography data currently used are:

1) different versions of ECOCLIMAP, from ECOCLIMAP 1 to ECOCLIMAP SG (Second Generation), depending on CSC,

2) the FAO, HWSD and Soilgrids sand, clay and soil-organic carbon databases,

3) the GMTED2010 orography,

4) the Global Lake DataBase (GLDB) v1-3.

We will continue to critically examine these databases and correct if possible, fixing errors, using national data, etc. We will develop parts of the code (PGD, scripts) to use these maps in different CSCs. We will study their impact and monitor the verification scores. Eventual modifications done on regional/domain level will be gathered to consortia wide versions of these databases. In collaboration with the SURFEX team at Météo-France such modifications may also lead to official updates of these databases, as published via the SURFEX web site by Météo-France. We will study the feasibility of creating the fine (hectometric scale) land cover map over Europe using Machine Learning techniques. Specific related tasks are organised under the Machine Learning WP, ML1.

We will coordinate possible physiography development with other consortia via EWGLAM/SRNWP.

Contributors, efforts: S. Oswald (Au) 1.5 PM; TOTAL: **1.5 PM**

Planned timeframe:

Planned deliverable: report and documentation updates

Status/description: ONGOING

Within the scope of the EUMETNET/C-SRNWP project ‘Evaluation and updates of ESA-CCIglobal land cover map for NWP needs’, Sandro Oswald continued his work by updating permanent snow pixels. The first step was to choose a proper platform to handle big data sets from Sentinel 2, wherein the Google Earth Engine (GEE) was chosen. Secondly, an adequate platform is needed for gathering issues in the land cover product and documenting incoming corrections, which pointed to Gitlab.

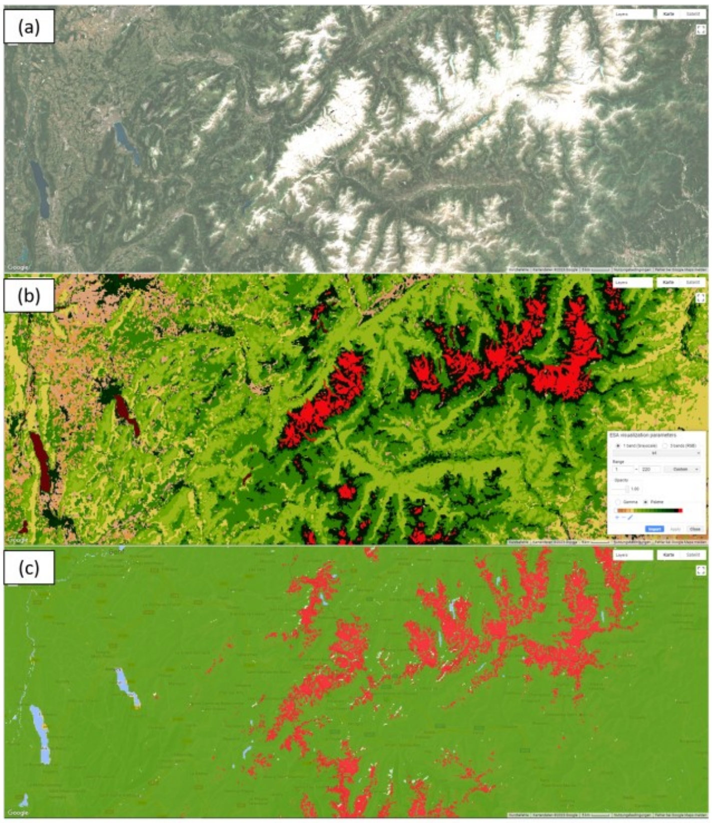

Fig. 6: Ilustration of the possibility to update the permanent snow/ice cells in ESA-CCI land cover map. (a) median of composite picture of the Sentinel 2 in 2023, (b) the update by using Sandro’s method and (c) the proposed method to update the snow/ice mask with actual Sentinel 2 products. Red cells mark snow/ice in (b) and (c).

The first step of the computation procedure was identifying snow and ice from satellite products. This was made using the algorithm from SentinelHub, based on the Normalized Difference Snow Index (NDSI), the Normalized Difference Vegetation Index (NDVI) and the brightness of Band 3. The clouds were excluded with the Scene Classification Map (SCL) of Sentinel 2, focusing on the period from 1st June to 30th September to identify only areas with permanent snow and ice in the northern hemisphere. A second step was to exclude water or moist areas with the already corrected ESA-CCI land cover map and using the Normalized Difference Moisture Index (NDMI) as a third threshold to detect snow/ice.

Comparing Fig. 6b and 6c, the overall accordance is good but updated ESA-CCI land cover map shows less snow/ice pixels than the proposed mask. The results depend on the year and its meteorological conditions. However, the factor of difference between the two might be the presence of dirt on glaciers. Further investigation is needed.

Action/Subject: Sub-km modelling (HR)

Description and objectives:

The main objective is to achieve up-to-date, realistic and affordable research and pre-operational versions of sub-km AROME-France, HARMONIE-AROME and ALARO. Research is now beginning to extend to the hyper-resolution (O(100-200m) horizontal resolution in grid point space) scale. This research is linked to developments on hectometric scale modelling in DEODE.

Aspects to be studied are

- numerical stability, particularly near steep topography;

- the meteorological and computational effects of using higher order than linear spectral grids;

- the need to revise or retune physics parametrizations, the settings of horizontal numerical diffusion and reworking of the SLHD (link with HR8.4);

- inspect the application limits of 1D physicis, i.e., the necessity of introducing 3D effects

- the provision and use of adequate physiography data;

- the availability and quality of observations suitable for the validation of hyper-resolution models;

- the validation and optimization of the model for urban environments.

Simulations of different weather situations are needed in order to study the interactions between resolved and parametrized processes related to convection, turbulence, waves, radiation and microphysics.

The tasks described here are closely related to the progress made in new dynamics schemes (DY1-2-3), 3D-physics (PH1-2-3), high-resolution physiography (SU5), new observation types (DA4) and suitable new validation and verification techniques for hyper-resolutions (MQA2). In addition to this, options for data assimilation settings, ensemble configurations, and computational efficiency aspects will also be considered. These experiments will be done on several (maritime and continental) test domains.

At sub-km and hyper-resolution scales, we enter the grey-zone of shallow convection and turbulence, and the physics parametrizations will need to be revised and retuned accordingly.

Field experiments will be used to validate and optimize aspects such as the microphysics (e.g. SOFOG3D) and the urban description (e.g. the WMO 2024 Paris Olympics project). Attention will be needed for developing computationally affordable 3D-schemes for radiation and turbulence (link with WP PH1-2). It will be assessed whether or not we run into limitations of our present spectral SISL dynamics (work closely related to the DY2-3 WP's).

Activities will also focus on horizontal and vertical diffusion (turbulence) on sub-km scales. The horizontal diffusion will be re-designed and tuned depending on the scale aimed to in the high resolution experiments. The computation of the SLHD diffusion coefficient will be modified to become a function of the total flow deformation. The relation between the horizontal diffusion applied by the model dynamics (SLHD or conventional spectral horizontal diffusion) and the parametrized vertical diffusion will be studied for a range of resolutions.

Contributors, efforts: M. Derkova (Sk) 0.25 PM, M. Nestiak (Sk) 0.75 PM, S. Schneider (At) 2.0 PM, P. Scheffkencht (At) 1.0 PM, P. Sekula (Pl) 0.25 PM, A. Simon (Sk) 3.0 PM, P. Smolikova (Cz) 5.25 PM, M. Tudor (Cr) 1.0 PM, C. Wittmann (At) 2.0 PM: TOTAL: **15.5 PM** (Physics only ~ **7.5 PM**)

Planned timeframe:

Planned deliverable: code modification, documentation updates

Sub-action: Studies with AROME in the very complex ALPINE terrain

Contributors: B. Wibmer (At) 0.25 PM

Efforts: 0.25 PM

Documentation, deliverable: stay report and code

Status/description: ONGOING

As part of the collaboration between Geosphere Austria and the University of Innsbruck, a student (B. Wibmer) and a newcomer (Daniel Deacu) were employed to work on research with the AROME model in the Alps, i.e. in the Inn valley. Under the supervision of Clemens Wastl, the first mentioned started working on his thesis entitled "Thermally-driven wind fields in the Inn-Valley", where he is investigating the performance of AROME running with different resolutions (2.5km - 1km - 500m), using the i-Box data from University. The preliminary results indicate that the overall structure of thermally-driven winds is well captured at different resolutions, while the onset and the magnitude are improving with the increase in resolution. The observed problems are mostly related to morning down-valley wind, which is generally too weak. Additionally, the impact of resolution is essential in resolving the structure of cross-valley flows (Fig. 7).

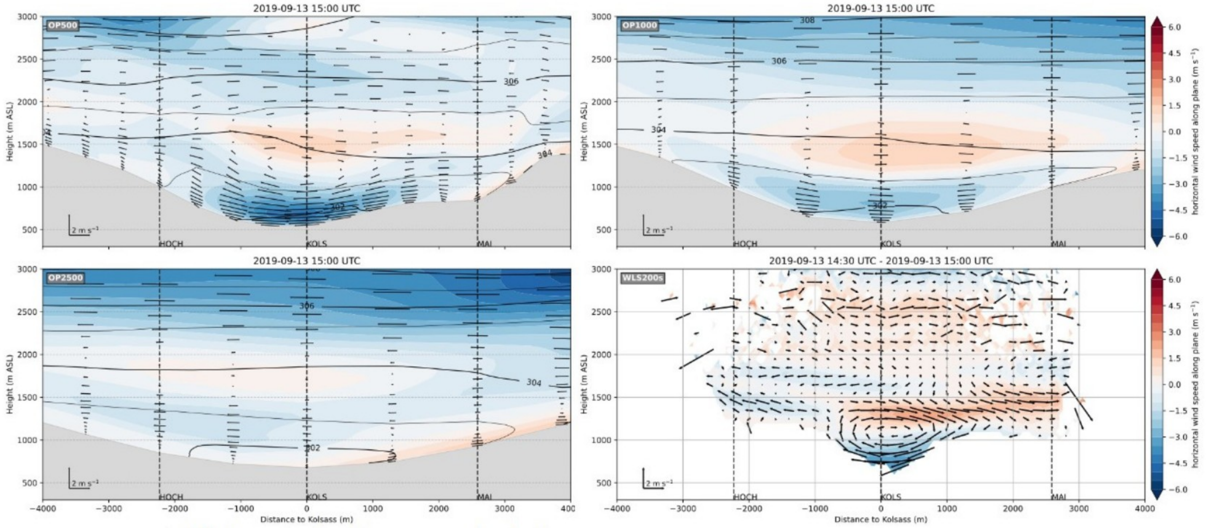

Fig. 7: Vertical cross-section through the Inn Valley and structure of related flow at: i) dx=500 m (upper left), i) dx=1 km (upper right), i) dx=2.5 km (bottom left), iv) from ground-based LIDAR (bottom right).

The research will continue during 2024. The newcomer is currently undergoing training and later will focus on the "Alpine Forecast problems" of AROME, starting with the stable boundary layer and the TEAMx model intercomparison study on "Cold Air Pools". Thereby, he will use the i-Box and TEAMx field campaign data for the comparison and work with MUSC.

Sub-action: Sensitivity tests with ALARO at SHMU

Contributors: A. Simon (Sk) 3.0 PM

Efforts: 3.0 PM

Documentation, deliverable: stay report and code

The tests with ALARO-CMC were performed on a case of a severe windstorm on 28 August 2023 in southwestern Slovakia. They were mostly related to the parameterization of graupel and using the explicit convection in CY48T3. It was found that the parameterization of graupel is essential in forecasting such storms, enhancing the predicted gusts by more than 10 m/s. The impact is considerably larger than the parameterized/explicit convection and comparable to the hydrostatic/non-hydrostatic dynamics (though we are at a horizontal resolution of 1 km as in SHMU's RUC).

It is also evident that the classic parameterization of wind gusts using dynamical velocity (u_*) systematically exaggerates wind gusts in outflows of thunderstorms (when using FACRAF around 10). It is probably related to the stratification in the outflow plume, which is usually quite stable (relatively high average wind speed, moderate gustiness), and the gust parameterization is somehow unable to describe these conditions correctly. On the other hand, the TKE-based gust parameterization, although scale-dependent, provides more realistic gust forecasts in such environment.

Action/Subject: Addressing future evolutions of software infrastructure (SPTR)

Description and objectives:

Prepare ACCORD codes for porting to GPUs. Regular meetings will be organized with ECMWF to ensure that the ACCORD activities stay aligned with the ones of ECMWF. An important constraint is that the vectorization and the performance on CPU-only machines should not be affected in a negative way.

The aim of this task is therefore to improve the flexibility of the code in terms of parallelization granularity. The code should be flexible enough to allow both for the existing coarse-grained parallelism with a single top-level OpenMP loop around the physics parameterizations, as well as for a finely granular layout where individual parameterizations are computed in separate parallel regions. The strategy to achieve this flexibility is to use source-to-source translator scripts to automatically generate the finely granular layout from the familiar coarsely granular layout. These scripts take care of the correct dimensioning of arrays, correct placement of NPROMA-block loops, wrapping of temporary arrays in FIELD_API structures. While a proof-of-concept of this strategy to has been developed and tested for ARPEGE and ALARO, further work is needed on the control routines of the AROME and HARMONIE-AROME configurations. It is also planned to rewrite the existing (perl) source-to-source translator scripts in the more future-proof Loki framework.

Contributors, efforts: B. Bochenek (Pl) 3.75 PM, R. Brožková (Cz) 2 PM, M. Hrastinski (Cr) 1.25, J. Mašek (Cz) 2 PM, M. Tudor (Cr) 1.5; TOTAL: **10.5 PM**

Planned timeframe:

Planned deliverable: code modification, documentation updates

Status/description: FINISHED

At the "Alaro Refactoring Working Week" (ARWW) held in Prague between 7-11 November 2022, a team consisting of the above contributors and Daan Degrauwe from RMI created a baseline version of the APL_ALARO subroutine and identified large blocks of computations and routine calls that belong together: i) initializations, ii) negative humidity correction, iii) surface and turbulence preparation, iv) mixing length calculations, v) turbulence and surface, vi) radiation, vii) deep convection, viii) microphysics and ix) diagnostics. For some of these blocks, an intermediate structuring routine was created to make APL_ALARO easier to handle. Additionally, some obsolete options and those not used by ALARO were removed.

The number of code lines was thus reduced from ~5000 (APLPAR) to ~2000 (APL_ALARO).

The work continued from home, and individual contributions were finalized in the summer. Then, Bogdan Bochenek merged them and phased to CY49T1, tested in DAVAI and submitted via a new GitHub environment. Finally, the contribution was approved and became a part of the common IAL code. Thereby, this preliminary phase of ALARO code refactoring is considered finalized. However, further debugging and optimizations within individual blocks and refactoring of other parts of the code will follow.

3 Documents and publications

List of reports:

Mario Hrastinski, 2023: Latest upgrades of TKE-based mixing length formulation and TOUCANS code, RC LACE stay, Prague, 17-28.7.2023. and 4-15.12.2023.

Piotr Sekuła, 2023: Study of the radiation, cloud's microphysics and atmospheric precipitation sensitivity by taking into account the atmospheric aerosols impact using the AROME model, ACCORD flat-rate stay, Helsinki, 11.04.2023-29.04.2023.

Piotr Sekuła, 2023: Study of the radiation, cloud's microphysics and atmospheric precipitation sensitivity by taking into account the atmospheric aerosols impact using the AROME model , RC LACE stay, Prague, 17.09.2023-14.10.2023.

Gabriel Stachura, 2023: Testing soil and snow schemes in SURFEX in ALARO, ACCORD flat-rate stay, Prague, 13.11.2023-08.12.2023.

Ana Šljivić, 2023: Towards the 46T1-based common MUSC experiment, ACCORD flat-rate stay, Helsinki, 03.04.2023-07.04.2023.

Ana Šljivić, 2023: Externalization of the effective radius from radiation, RC-LACE stay, Prague, 25.09.2023-20.10.2023.

List o scientific papers:

Hrastinski, M., Mašek, J. and Šljivić, A., (2024): Improving the Near-Surface Wind and Turbulence at the Edge of the Orographic Drag Gray Zone by Tuning the Roughness Length. Mon. Wea. Rev., 152, 413–432, DOI: 10.1175/MWR-D-23-0178.1

Němec, D., Brožková, R. and Van Ginderachter, M., (2023): Developments of Single-Moment ALARO Microphysics Scheme with Three Prognostic Ice Categories (submitted to Tellus A)

Somfalvi-Tóth K and Simon A., (2023): Extreme Value Analysis and Modelling of Wet Snow Accretion on Overhead Lines in Hungary. *Atmosphere*, **14:81**, DOI: 10.3390/atmos14010081

4 Activities of management, coordination and communication

Planing of stays and adaptations of the plan for 2024 by the current Area Leader Mario Hrastinski (within the period 1.10-31.12.2023.).

5 Research stays

Three RC-LACE stays were executed (12 weeks in total):

- Latest upgrades of TKE-based mixing length formulation and TOUCANS code – Mario Hrastinski (2 weeks + 2 weeks, CHMI, Prague)
- Study of the radiation, cloud's microphysics and atmospheric precipitation sensitivity by taking into account the atmospheric aerosols impact using the AROME model - Piotr Sekuła (4 weeks, CHMI, Prague)
- Externalization of the effective radius from radiation – Ana Šljivić (4 weeks, CHMI, Prague)

Three ACCORD flat-rate stays were executed (8 weeks in total):

- Study of the radiation, cloud's microphysics and atmospheric precipitation sensitivity by taking into account the atmospheric aerosols impact using the AROME model - Piotr Sekuła (3 weeks, FMI, Helsinki)
- Testing soil and snow schemes in SURFEX in ALARO - Gabriel Stachura (4 weeks, CHMI, Prague)
- Towards the 46T1-based common MUSC experiment - Ana Šljivić (1 week, FMI, Helsinki)

6 Summary of resources

Summary of resources for the year 2023 is presented in Table 1.

Table 1. Resources per WPs and summary

	Manpower		LACE stays		ACCORD stays	
Subject/Action	**planned**	**realized**	**planned**	**realized**	**planned**	**realized**
PH1: Turbulence and shallow convection	11.00*	10.75*	1.00	1.00	0.0	0.0
PH2: Radiation	0.25	0.00	0.00	0.00	0.00	0.00
PH3: Clouds-precipitation microphysics	9.25	7.75	0.00	0.00	0.00	0.00
PH4: Common 1D MUSC framework for parametrization validation	0.25	0.75	0.00	0.00	0.00	0.00
PH5: Model Output Postprocessing Parameters	2.00	5.25	0.00	0.00	0.00	0.00
PH6: Study the cloud/aerosol/radiation (CAR) interactions	6.00	9.00	2.00	2.00	1.00	1.00
PH7: On the interface between the surface and the atmosphere	8.25	10.00	0.00	0.00	0.00	0.00
PH8: On the interface of Physics with Dynamics (and time stepping)	0.00*	0.00*	1.00*	1.00*	0.00	0.00
SU3: SURFEX: validation and development of existing components for NWP	5.00	5.00	0.00	0.00	1.00	1.00
SU5: Assess/improve quality of surface characterization	4.00	1.50	0.00	0.00	0.00	0.00
HR: Sub-km modelling	4.50*	7.50*	0.00*	0.00*	0.00*	0.00*
SPTR: Addressing future evolutions of software infrastructure	12.00	10.50	0.00	0.00	0.00	0.00
TOTAL	62.50	68.50	3.00	3.00	2.00	2.00

(*) accounted for in "Dynamics and coupling" area (at least partly)

7 References

Canuto, V., (1992): Turbulent convection with overshootings: Reynolds stress approach. *J. Astrophys.*, **392**, 218–232, DOI: 10.1086/171420

Cheng, Y., V. Canuto, and A. Howard, (2002): An improved model for the turbulent PBL. *J. Atmos. Sci.*, **59**, 1550–1565, DOI: 10.1175/1520-0469(2002)059<1550:AIMFTT>2.0.CO;2.

Hrastinski., M., (2022): Recent developments of the TKE-based mixing length formulation in TOUCANS. RC-LACE stay report, Prague, 11th -22nd July and 15th -26th August 2022.

Hrastinski., M., (2023): Latest upgrades of TKE-based mixing length formulation and TOUCANS code. RC-LACE stay report, Prague, 17th -28th July and 4th -15th December 2023.

Khairoutdinov M and Kogan Y., (2000): A new cloud physics parameterization in a large-eddy simulation model of marine stratocumulus. *Mon. Weather Rev.*, **128**, 229–243., DOI: 10.1175/1520-0493(2000)128<0229:ANCPPI>2.0.CO;2

Mašek, J., I. Bašták Ďurán, and R. Brožková, 2022: Stable Numerical Implementation of a Turbulence Scheme with Two Prognostic Turbulence Energies. *Mon. Wea. Rev.*, **150**, 1667–1688, DOI: 10.1175/MWR-D-21-0172.1.

Oreopoulos, L., N. Cho, and D Lee, 2022: Revisiting cloud overlap with a merged dataset of liquid and ice loud overlap cloud extinction from CloudSat and CALIPSO. *Front. Remote Sens.*, ***3***, *1076471*, *DOI:* 10.3389/frsen.2022.1076471.

Rodier, Q., V. Masson, F. Couvreux, and A. Paci, (2017): Evaluation of a Buoyancy and Shear Based Mixing Length for a Turbulence Scheme. *Front. Earth Sci.*, **5**, DOI: 10.3389/feart.2017.00065