Working Area Physics

Progress Report

Prepared by:	Physics Area Leader Mario Hrastinski
Period:	1.1-30.6.2024.
Date:	16th September 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) 6.00 PM, M. Hrastinski (Cr) 4.25 PM, J. Mašek (Cz) 1.25 PM and P. Smerkol (Si) 7.75 PM; TOTAL: **19.25 PM**

Planned timeframe:

Planned deliverable: code modification, documentation updates

Sub-action: Turbulence length scale computation

Contributors: R. Brožková (Cz) 6.00 PM, M. Hrastinski (Cr) 4.25 PM and J. Mašek (Cz) 0.75 PM

Efforts: 11.00 PM

Documentation, deliverable: stay report and code

Status/description: ONGOING

The development of TKE-based Turbulence Length Scale (TLS) in TOUCANS is considered finalized. The solution includes (i) scaling the average vertical displacement (L_{TKE}) with von Kármán's constant (κ), (ii) blending L_{TKE} with κz TLS in the surface layer, (iii) adjusting the minimum allowed TLS 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}), and (iv) a constant, non-vanishing, upper-air TLS (L_{UTLS}) with a linear transition (L_{TRANS}) to L_{BLT} (see Fig. 1). The latter is necessary to support 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}.

The TKE-based TLS formulation was previously validated in different weather situations, including convection and inversion. The first results suggested a considerable improvement in forecasting (i) the inversion-related low-level clouds and (ii) temperature and wind profiles. However, some improvement in precipitation patterns during the convection was also observed. Extending the number of above cases showed a neutral to slightly positive signal.
Recently, the new TLS formulation was compared to the LES-derived equivalent. Furthermore, a single-column version of the NWP model was launched to extract vertical

profiles of turbulent fluxes and associated mean fields. The analysis pointed to the added value in simulating a very stable planetary boundary layer and situations with stratocumulus clouds while maintaining nearly neutral performance in convective cases. The development of the TKE-based TLS formulation and its validation are summarized in a paper entitled “Regime-dependent turbulence length scale formulation for NWP models based on turbulence kinetic energy, shear and stratification, which is submitted to the Monthly Weather Review.

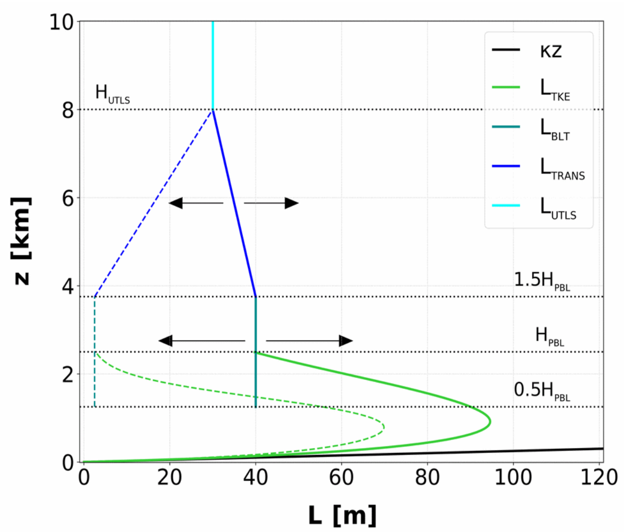

Fig. 1: Schematic representation of unified and regime-dependent turbulence length scale formulation based on prognostic TKE, shear and buoyancy. The contents of the legend, i.e., TLSs, are explained above in the text.

The related development are phased to CY46 and included in the new version of the RC-LACE ensemble system A-LAEF, while the document on how to use and tune the TKE-based TLS formulation is being prepared. Future efforts are mainly focused on optimizing the performance of the TKE-based TLS formulation and eventual operational application.

Despite the above results, fine-tuning of internal parameters and a more extensive validation are required before the operational implementation. The related activity is ongoing at CHMI. In a nearly dry case, the verification T2m scores indicate that (i) TLS tuning reduces the existing daytime BIAS (cold) and RMSE and (ii) tuned TKE-based TLS has even smaller nighttime BIAS (warm) and RMSE than the operational reference. The validation and tuning continued in more cloudy cases, encompassing thermodynamic adjustment, radiation cloud scheme, vegetation thermal coefficient and resistance to evaporation. A set-up/tuning was proposed. However, it is likely not the final one.

Generally, the TKE-based TLS, with the latest tuning, improves screen level scores, namely biases. However, the remaining problem is a slightly increased standard deviation of T2m, RH2m and 10-m wind scores in the afternoon of a summer convective period. Additionally, the lower troposphere scores are also slightly deteriorated. Finally, while the precipitation scores seem better, a situation with a missed convective system is observed in southern Poland (see Fig. 2).

Among the options still to address, the first two are (i) the method to determine the PBL height (H_{PBL}) and (ii) the moist gustiness correction. The TKE profile-based H_{PBL} method, used with the TKE-based TLS formulation, exhibits a horizontally noisy pattern, while its improvement can potentially reduce the standard deviation scores. Further, the moist gustiness scheme reacts quite differently to the TKE-based TLS formulation than the reference formulation. Therefore, its minor revision is foreseen.

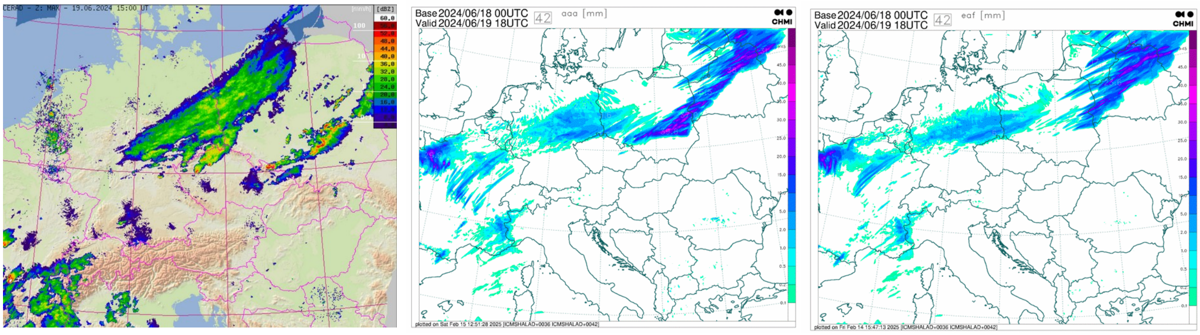

Fig. 2: 6-h accumulated precipitation between 12:00 and 18:00 UTC 19 June 2024 from (i) radar (left), (ii) reference TLS forecast (middle) and (iii) TKE-based TLS forecast (right).

Sub-action: Third-Order Moments (TOMs)

Contributors: J. Mašek (Cz) 0.50 PM and P. Smerkol (Si) 7.75 PM

Efforts: 8.25 PM

Documentation, deliverable: short report and documentation

Status/description: ONGOING

Peter Smerkol continued his work on stabilizing the TOMs solver (ACDIFV3 subroutine), following the plan from the TOUCANS brainstorming held in 2022. Therein, it was concluded that the numerical instability might be related to (i) the use of virtual (instead of entropy-based) potential temperature in the solver, (ii) the additional temporal term, (iii) applying the TOMs solver in the moist case, i.e., the most complex one, and (iv) questionable assumptions in the derivation of solver equations.

The focus in the Q1 of 2024 was still on revising the theory and preparing the documentation. The former aimed at 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, e.g., in the closure of third-order pressure-velocity gradient terms, were found and should be investigated later but are not expected to affect the stability of the solver.

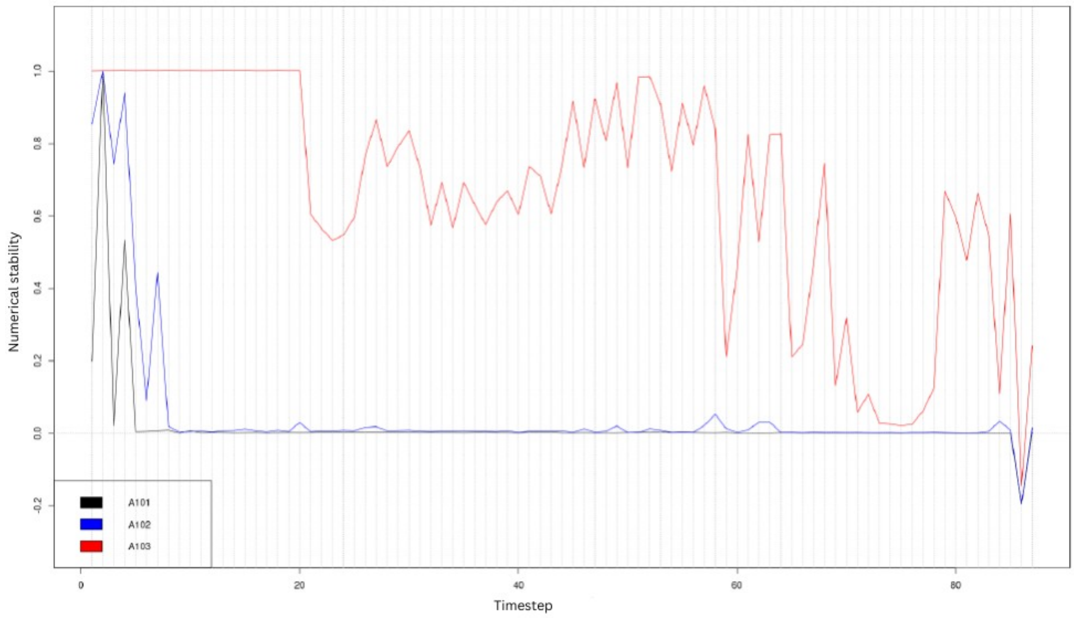

Fig. 3: The numerical stability of TOMs solver given by the diagonal dominance factor (closer to 1 is more stable) within first hours of the 7th September 2023 dry case. The content of the legend is (i) A101 – the reference with all bugs, (ii) A102 – the experiment with all bugs corrected, except the ZZZ bug, and (iii) A103 – the experiment with all bugs corrected, the time term added and fixed limit of TKE).

Simultaneously, the influence of fixing the known bugs in the ACDIFV3 subroutine was investigated (in a dry case). Their impact was small, except for the bug in the ZZZ term, which involves an extra division with the timestep. After its fixing, the model crashed after a few timesteps. The only remaining step was to include the so-called temporal term, as described in the TOUCANS documentation but missing in the code.

After additional theory revision and discussion, it was revealed that assumptions resulting in the vanishing of the so-called temporal term do not hold. Adding it to the TOMs solver enhanced the diagonal dominance and, thus, the numerical stability. However, the model still crashed, although somewhat later in the forecast. The remaining instability was caused by variables ZITKE and ZITAU2TKE, which contain TKE in the denominator, limited to 10^{-8}. Following the limitation of TKE to 10^{-4} (in the ACDIFV3 subroutine only), the simulation was stable for 24 hours (see Fig. 3). Additionally, the contribution of TOMs to heat and moisture fluxes was several per cent but still ~ 50 times larger than within the reference experiment (with the ZZZ bug), which seems reasonable. The evaluation will continue in cases with potentially larger impact of TOMs, i.e., with pronounced counter-gradient and non-local components.

During the summer, it was found that some terms of the TOMS solver are missing at KLEV and KLEV-1, resulting in generally improved stability when introduced. However, they are not included in the Jean-Francois' protection mechanism and the code still crashes occasionally. This raised a need for additional theory inspection.

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.

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: Mašek, J. (Cz) 0.50 PM; TOTAL: **0.25 PM**

Planned timeframe:

Planned deliverable: NONE

Status/description: ONGOING (but slowly)

The radiation-related activities were mostly focused on introducing CAMS aerosols with three CMCs (see PH6 action/subject).

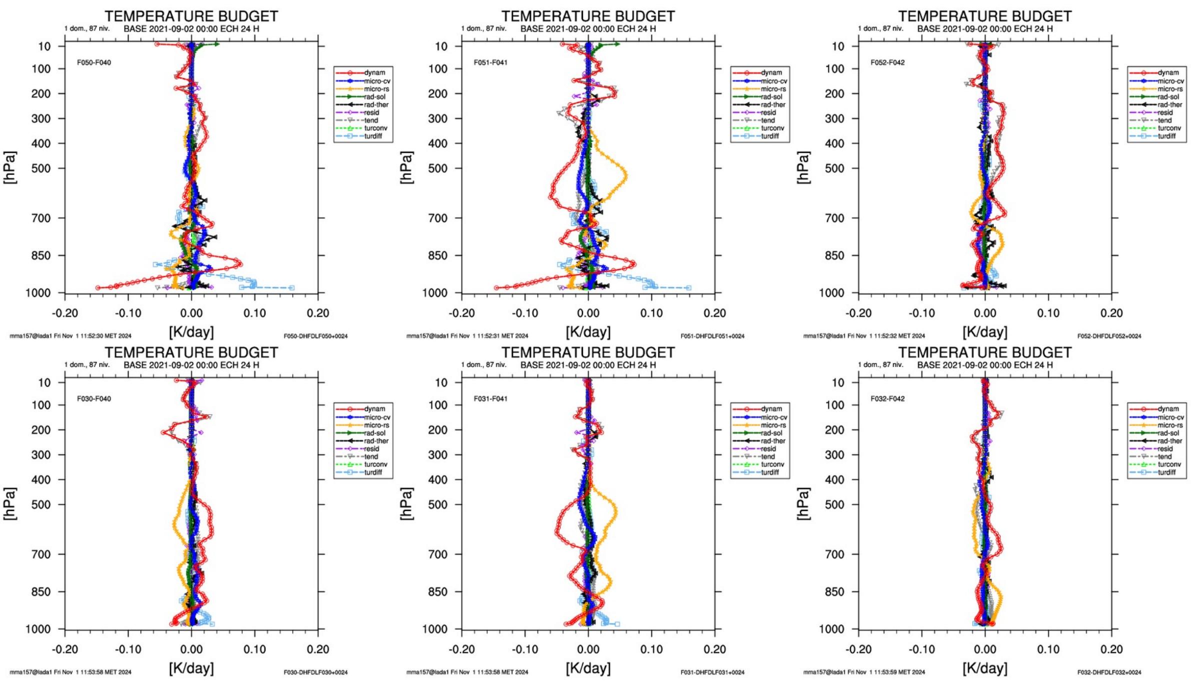

Fig. 4: The intermittency tests for the old IFS scheme (left), ecRad (middle) and ACRANEB2 (right). The upper panels show differences in +24-h DDH temperature budgets between 1-h intermittency and the reference (no-intermittency), while lower panels show corresponding differences between 15-min intermittency and the reference.

Besides this, there is an ongoing activity of interfacing ecRad scheme with ALARO CMC, being covered during Sophia Schaefer's one-week stay in Prague (supported by ACCORD). Thereby, an intercomparison of ACRANEB2, ecRad, and old IFS radiation was conducted, focusing on the first two as operational choices in ALARO and ARPEGE/AROME-MF. The comparison was conducted in (i) a single-column model and (ii) a 3D ALARO CMC model on CY48T3. Related to (i), a procedure was created to convert ACRANEB2 ASCII input to ecRad NetCDF input. The two radiation scheme settings were kept as close as possible. However, achieving complete consistency in cloudy cases was not feasible due to differences in cloud optics. Additionally, the narrowband model, used to fit ACRANEB2 transmissions, was compared against ecRad, showing a good match for clear-sky fluxes but limited accuracy in ACRANEB2 shortwave fluxes.

The 3D comparison focused on intermittency settings, related CPU cost, and the impact on DDH profiles (compared to reference non-intermittent runs). The CHMI's operational domain with dx=2.33km, 87 vertical levels, and a time-step dt=90s was utilized. Thereby, it was shown that (i) ACRANEB2 with selective intermittency is more consistent than ecRad with full intermittency (Fig. 4), (ii) for 15-min intermittency and no-intermittency ecRad is 5% and 35% more expensive than other schemes, (iii) the accuracy of ecRad transmissions is superior to ACRANEB2 and (iv) the change in radiation scheme has bigger impact than the change in intermittency settings.

Other possible/relevant topics, e.g., addressing 3D effects and revision of broadband gaseous transmissions (or a hybrid approach to them) are considered “not easy to win” or not that urgent.

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: D. Němec (Cz) 9.25 PM; TOTAL: **9.25 PM**

Planned timeframe:

Planned deliverable: code modification, short report and namelist

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

Contributors: D. Němec (Cz) 9.25 PM

Efforts: 9.25 PM

Documentation, deliverable: short report and code modification

Status/description: ONGOING

In Q1 and Q2, David Němec continued developing the two-moment scheme within the ALARO-CMC (at least for some species). The aim of the two-moment microphysics scheme is that the model can better handle various precipitation regimes as there are two degrees of freedom in the size distribution of the particles, e.g., smaller raindrops in the drizzle from stratus and bigger raindrops from melting the snow and graupel (even if the rain flux is small).

First, in Q1, the two-moment cloud water and its aerosol sensitivity were implemented. Using CAMS aerosol climatology, CAMS near real-time aerosols, or a prescribed number of aerosols for droplet number concentration in microphysics is possible. Second, in Q2, the focus was mainly on the two-moment-related rain. Therein, the rain droplet size distribution follows the generalized gamma distribution. A new process, i.e., self-collection/break-up, is added when two raindrops merge into one or one raindrop breaks into many.

The first tests show the expected behaviour of the mean volume diameter: smaller drops in drizzle and bigger drops in convective storms. Concerning the vertical profile, unlike the one-moment scheme, the two-moment scheme can produce two maxima of the mean volume diameter (see Fig. 5): (i) in the higher altitudes connected to melting (positive; as snow and graupel particles are big, so after melting, we should get large drops) and (ii) near the ground due to collection of cloud water by rain and self-collection of raindrops. The development of the two-moment scheme will continue during David's research stay at the University of Ghent in Q3 and beyond (locally).

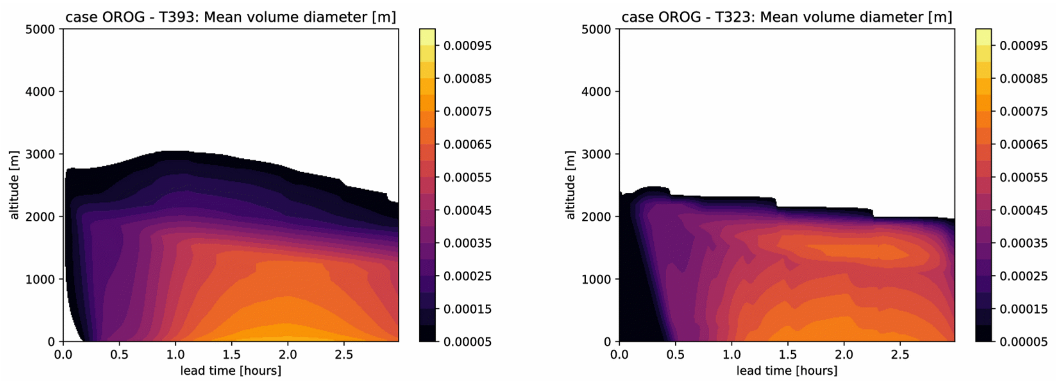

Fig. 5: Time evolution of the vertical profile of mean volume diameter during the orographic lift case in MUSC obtained by utilizing: (i) one-moment scheme, i.e., current operational setup of CHMI (left) and (ii) two-moment scheme (right).

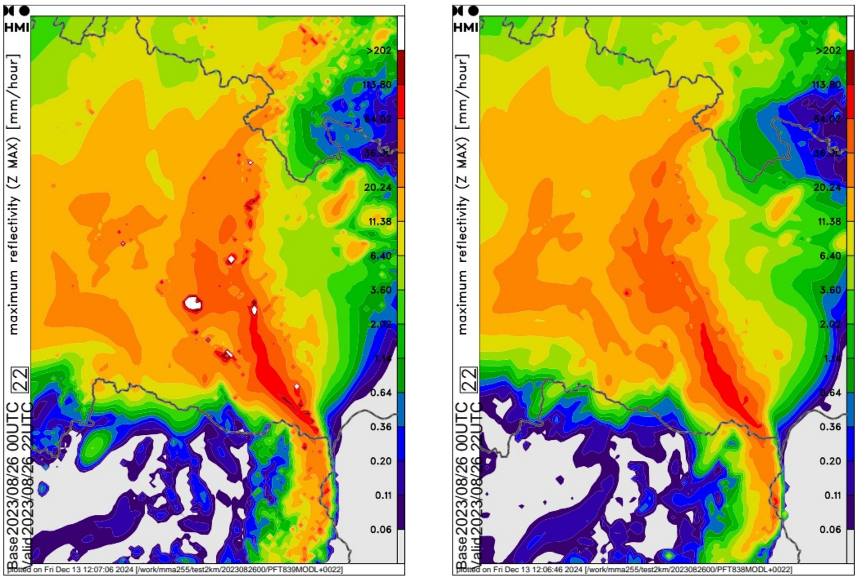

Fig. 6: Maximum radar reflectivity with: old non-monotonic (left) and new quasi-monotonic interpolator (right) for all hydrometeor mass fractions and number concentrations.

In Q3 and Q4, the focus was on further development of two-moment microphysics, including (i) rain and cloud water (Q3 and early Q4) and (ii) ice (late Q4). The rain parameterization is mostly finished, providing reasonable and numerically stable results. However, it requires further tuning. Key improvements include: the autoconversion scheme, introducing a variable shape parameter of the gamma distribution, adjustments of self-collection/collisional breakup and implementing a quasi-monotonic interpolator for all hydrometeor mass fractions and number concentrations (to prevent numerical artifacts in radar reflectivity; see Fig. 6). However, it should be noted that the quasi-monotonic interpolator is less accurate and may be replaced if a more suitable solution is found.

In contrast, the ice-related research has only started. There are many cases when it does not work well in a 3D model, resulting in too little precipitation. However, mixed-phase situations (MPACE case) in 1D simulations seem more realistic as liquid cloud water production aligns better with observations.

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: D. Němec (Cz) 0.75 PM; Total: **0.75 PM**

Planned timeframe:

Planned deliverable: code contribution and stay report

Status/description: ONGOING

David Němec attended the MUSC WW in De Bilt in February, followed by preparation of the forcing to test ALARO physics for various cases, including ARM, BOMEX, DYCOMS-II, FIRE, GABLS1, MPACE, NORUNDA, SCLD and SCLO. The documentation on using MUSC in LACE and a description of the above cases are being prepared. The current situation is such that:

a) To run the MUSC simulation we only need (i) the INIT file (standard ICMSHALADINIT) and (ii) the namelist (with forcing for the particular case), i.e., there is no need to install something new. The INIT files and case-specific namelists (with the current operational configuration used at CHMI) are stored locally at CHMI.

b) MUSC can be launched on our local machines, using a script for the 3D model, with only minimal changes: (i) a different INIT file and the namelist and (ii) a few machine-related settings (e.g., the number of nodes).

For the ALARO-CMC, the above cases are prepared for testing. If needed, a support is available for AROME colleagues.

Additionally, for most of the above cases, there are available outputs from the MicroHH and MesoNH LES simulations and stored locally at CHMI. The aim is to finalize the documentation and description of the existing cases by the end of the year and to continue gathering the necessary data for the validation (from super-sites, Cloudnet, LES simulations, etc.).

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 (i.e., 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: C. Wittmann (At) 0.50 PM and A. Simon (Sk) 2.75 PM; TOTAL: **3.25 PM**

Planned timeframe:

Planned deliverable: code modification, documentation updates

Status/description: ONGOING

Within this package, activities in Q1 and Q2 were mainly related to phasing previous developments into higher cycles (mainly CY48T3), e.g., mean radiant temperature (AROME; for DEODE) and wet snow accretion and maximum subgrid wind (ALARO). In addition, at SHMU, tests in the ALA2E model were performed, i.e., ALARO-based downscaling to 2 km resolution (with initial conditions from the A-LAEF control member and LBC from the ECMWF). The associated activities are summarized below in a separate sub-action.

Sub-action: The wet snow accretion and prognostic graupel schemes in ALA2E/SHMU model

Contributors: A. Simon (Sk) 2.75 PM

Efforts: 2.75 PM

Documentation, deliverable: short report and code modification

Status/description: ONGOING

In Q1 and Q2, the operational ALA2E model was switched from CY43T2 to CY48T3. Therein, the prognostic graupel treatment was introduced, mainly to get additional diagnostic parameters: storm-relative environmental helicity, DIAGFLASH, MLCAPE, MUMLCAPE, cloud base, cloud top pressure, etc.

Further, the impact of the prognostic graupel was validated in several situations in both winter and summer. During the winter, a big portion of snow (mainly wet snow) has been identified as graupel, which can be partly reduced by decreasing the value of the RWBF1 parameter (NAMPHY0). In the summer, activating the prognostic graupel scheme increases precipitation amount and intensifies the outflows of deep convection and the wind gust speed. This effect is partially positive but in certain situations, the model versions using prognostic graupel showed less realistic convection development, e.g. non-realistic precipitation, different structures in convection, etc.. The evaluation is not yet finished and was focused on the prognostic graupel due to the expected largest impact compared to the reference model version.

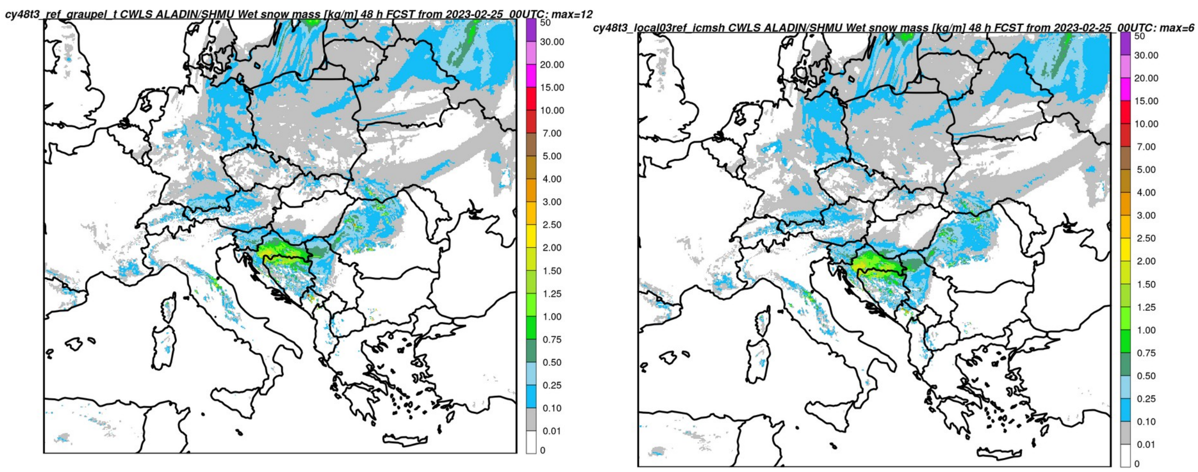

Fig. 7: The accreted wet snow mass with (left) and without (right) graupel in the associated parameterization scheme for the 25th February 2023 case.

In Q3 and Q4, graupel was introduced in the wet snow parameterization (acwsnow.F90) within CY48T3 at SHMU. This was necessary because prognostic graupel in ALARO (LGRAPRO=.T.) transforms a large portion of winter precipitation (snow, snow pellets, mixed precipitation, or rain) into graupel, even at the surface. To avoid underestimating wet snow, graupel was integrated into wet snow parameterization as a kind of "temporary fix" until a prognostic graupel scheme is improved, e.g., its fall speed.

The ALADIN/SHMU CY48T3 tests show that when graupel is activated, wet snow precipitation and accreted mass increase, particularly in mountainous regions. There, the wet snow mass nearly doubles and is likely overestimated. In addition, the impact on wet snow fields is relatively small elsewhere (Fig. 7). On the contrary, in the plains, the wet snow mass even decreases. This modification has been operational in the ALA2E model since 27 November 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: R. Brožková (Cz) 0.50 PM, J. Mašek (Cz) 2.00 PM, P. Sekuła (Pl) 1.50 PM and A. Šljivić (Cz) 2.75 PM; TOTAL: **6.75 PM**

Planned timeframe:

Planned deliverable: code contribution, technical and stay reports

Status/description: ONGOING (operational validation; development is finished)

Developments within the CAR project reached a mature state for the radiation component using the ACRANEB2 scheme, with minor code modifications and inspection of aerosol background values still foreseen. Thus, it was enabled to replace the old Tegen et al. (1997) aerosol climatology with new CAMS aerosols, including the (i) 2D or 3D climatological values and (ii) 3D near real-time (n.r.t.) values. Additionally, some hybrid options, i.e., between 2D and 3D approaches are considered.

Unlike Tegen et al. (1997) climatology, which includes aerosol optical depth at 550 nm for 6 aerosol species, the 2D CAMS climatology contains vertically integrated mass per unit of area for 11 aerosol species. In the CAMS case, the option to utilize a more realistic vertical aerosol redistribution based on the gamma distribution is enabled within the new subroutine radaecmr.F90. Following the investigation of 3D CAMS climatology, the proposal is given for different exponents in the distribution for each aerosol type and month.

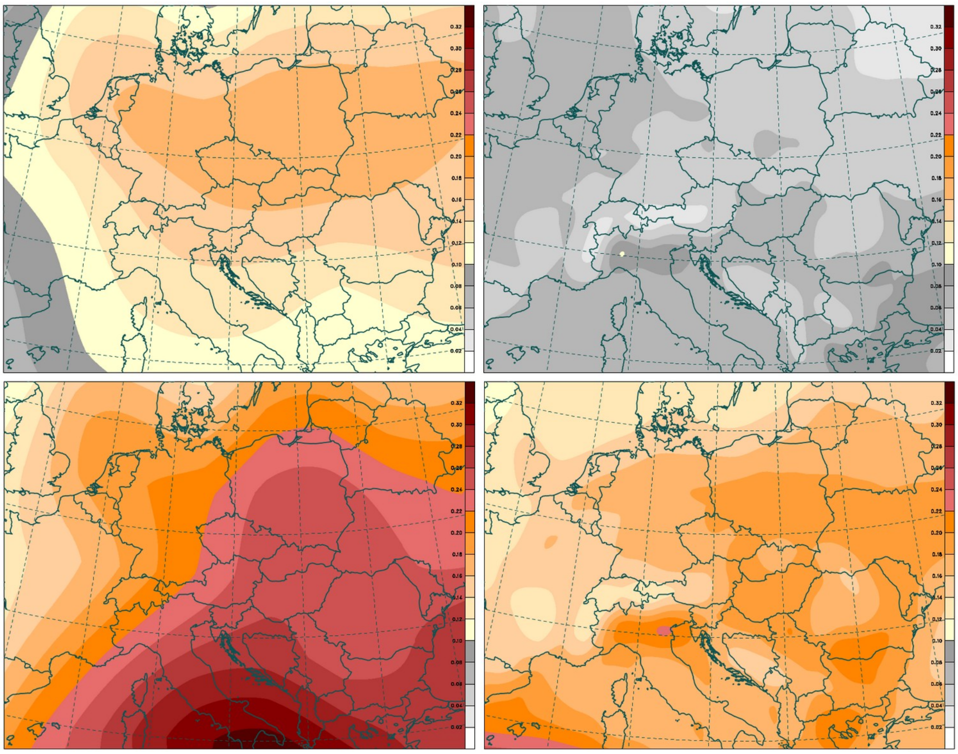

Fig. 8: Total aerosol optical depth at 550 nm (mixture of all tropospheric aerosols) for: (i) Tegen et al. (1997) climatology in January (upper left), (ii) CAMS 2D climatology in January (upper right), (iii) the same as (i) but for July, and (iv) the same as (ii) but for July. Gray to color transition at AOD=0.1.

Another aspect that needed to be adjusted were background values. It was decided to keep one tropospheric and one stratospheric background value. Additionally, the sulfuric background is supposed to be treated under the key LAEROVOL=.T. Their initial values were derived by transforming Tegen background values, projecting them to the corresponding CAMS type (hydrophobic organic matter for tropospheric and stratospheric background) and tuning them to have a similar impact on shortwave radiation as for Tegen climatology. There are associated documents on the above work published on the RC-LACE page (physics section): (i) describing the procedure to prepare CAMS aerosol inputs for climate files and (ii) elaborating the vertical redistribution of climatological values.

The 2D climatological aerosols are ready to be tested within the e-suite at CHMI (see Fig. 8 for a comparison with previous Tegen et al. (1997) fields). Contrary, for the near real-time option some logistical issues should be addressed first to optimize the cost vs. benefit ratio. The latter also includes the link with microphysics, where CAMS-based aerosols are essential for developing the two-moment scheme.

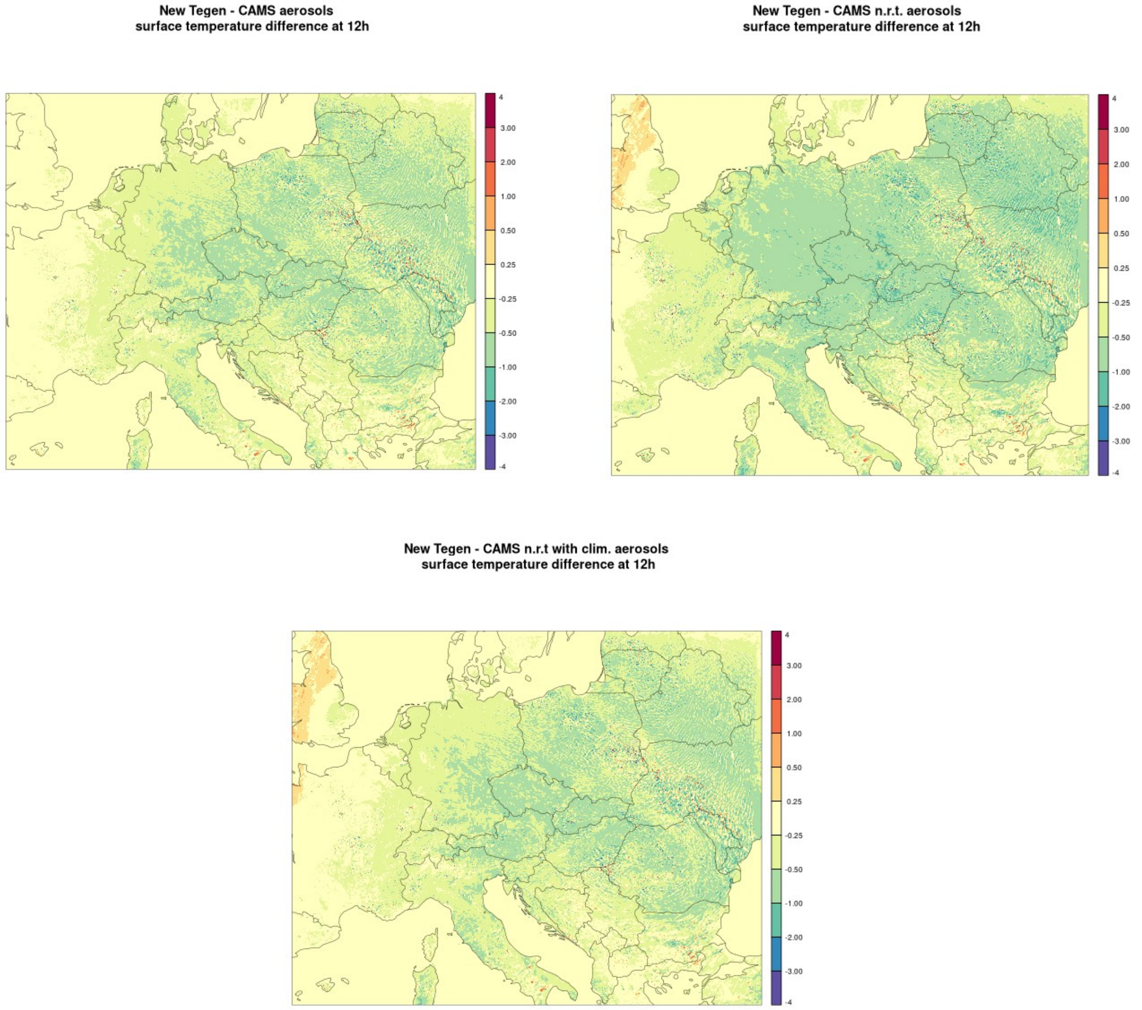

Fig. 9: Comparison of predicted surface temperature at 12 UTC on 7th September 2023 for experiments with: (a) Tegen and CAMS climatological aerosols, (b) Tegen and near-real time CAMS aerosols and (c) Tegen and combined near-real time (only 3 dust species) and climatological CAMS aerosols (8 of 11 aerosol species) for the final branch including all modifications.

Later, during the stay of Piotr Sekuła at CHMI (Q4), the data flow for CAMS aerosols was finalized, additionally enabling a mixture of 2D climatological and 3D n.r.t types. The motivation is to introduce the possibility of using expensive 3D n.r.t. aerosols only for quickly evolving desert dust. Therefore, GFL fields are exploited to carry aerosol MMRs, enabling also their coupling and advection. Possible undershoots are treated equivalently to the specific humidity, conserving the aerosol column mass. The aerosol dataflow can be used for all three CMCs. In addition, the e923 configuration was extended by step 12, enabling interpolating global CAMS 2D aerosol climatology to any LAM domain. The associated code is submitted to CY50T1. The final code also contains some previous developments by Jan Mašek, Laura Rontu and Ana Šljivić, including (i) reading 2D CAMS climatological aerosols, (ii) externalization of ACRANEB2 aerosols, (iii) conversion of CAMS MMRs to aerosol optical properties, (iv) the vertical distribution of 2D CAMS climatological aerosol and (v) externalization of the effective radius from ACRANEB2 scheme.

The validation was carried out with the ALADIN-CZ model on 7th September 2023 case. The proposed final code had a minor impact on reproducibility, while differences compared to the reference were estimated as acceptable. More significant differences were observed between experiments using different aerosol sources. For example, the experiment with Tegen aerosols resulted in a surface colder by 0.5-1°C after 12 hours of integration, compared to those from the CAMS database; climatological, n.r.t option or combination (Fig. 9).

Finally, at CHMI, steps towards the 2D CAMS aerosols operational application have been undertaken. Compared to Tegen, CAMS aerosol levels are lower, resulting in more solar radiation reaching the ground and decreased atmospheric absorption. Therefore, tuning other schemes is needed. It will follow after the equivalent process associated with the TKE-based TLS; addressing both simultaneously would be too complex.

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) 0.75 PM, M. Hrastinski (Cr) 1.00 PM and J. Mašek (Cz) 0.75 PM; TOTAL: **2.50 PM**

Planned timeframe:

Planned deliverable: code modification, short report

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

Contributors: R. Brožková 0.75 PM and J. Mašek (Cz) 0.50 PM

Efforts: 1.25 PM

Documentation, deliverable: short report

Status/description: FINALIZED

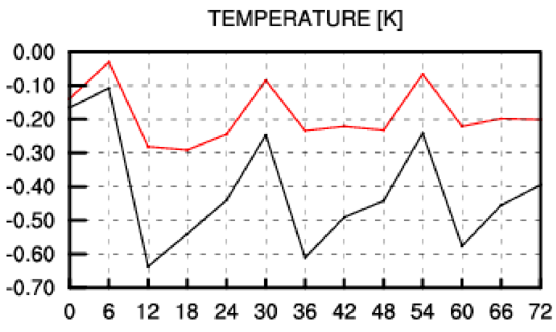

Fig. 10: The temperature BIAS for the 00 UTC run with the ALADIN-CZ model (with ALARO-1 physics) over the Central Europe in the period 9th-22nd January 2024 for: (i) the reference setup (WCRIN=4) and (ii) retuned setup (WCRIN=10).

After switching to 3-h cycling at CHMI, they stopped to relax the snow cover (reservoir of its water equivalent) to the climatology. Even if weak, the relaxation resulted in underestimating the snow cover (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 utilized 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. The influence of a related WCRIN parameter was investigated (changed from WCRIN=4 to its default value WCRIN=10). It resulted in a smaller surface covered by snow within the grid box and helped to correct the cold temperature bias (see Fig. 10). The modification was introduced to the e-suite.

Sub-action: Analysis of ALARO biases in temperature

Contributors: J. Mašek (Cz) 0.25 PM

Efforts: 0.25 PM

Documentation, deliverable: short report

Status/description: FINALIZED (likely to be continued in future)

The experiments were performed using the ALARO-CMC with ISBA in a climate mode. With the freely evolving surface, we suffer from cold bias in spring and summer. Tests have shown that it can be decreased by reducing the soil depth (to increase runoff) and utilizing the latest ALARO operational configuration, i.e., with prognostic graupel and retuned snow fraction. Still, the 2-m temperature bias in the climate mode remains significant and requires bias correction.

Sub-action: Modifying the code to distinguish vertical levels 'seen' by dynamics and turbulence

Contributors: M. Hrastinski 1.00 PM

Efforts: 1.00 PM

Documentation, deliverable: code modification and stay report

Status/description: ONGOING

To enable a safe decrease of the lowest model level and keep using the constant flux approximation in the turbulence scheme, the related code needed to be revised. Therefore, a new variable KLEVTUR was defined in YOMDIM and replaced KLEV in all TOUCANS-related subroutines. By definition KLEVTUR<=KLEV, while in the case KLEVTUR=KLEV, the computation should be identical to the previous, i.e., without modifications.

The above replacement was mostly straightforward, except where computations are done at the lowest half-level, i.e., surface (KLEV). For these, the necessary 1D arrays (horizontal) are passed from the APLPAR subroutine, thus avoiding the simultaneous use of KLEV and KLEVTUR within the TOUCANS subroutines. Further, it is ensured that KLEVTUR is used as the forcing level, while the choice of A and B coefficients to define vertical levels should be made to place KLEVTUR above the interpolation levels, i.e., 2 and 10-m.

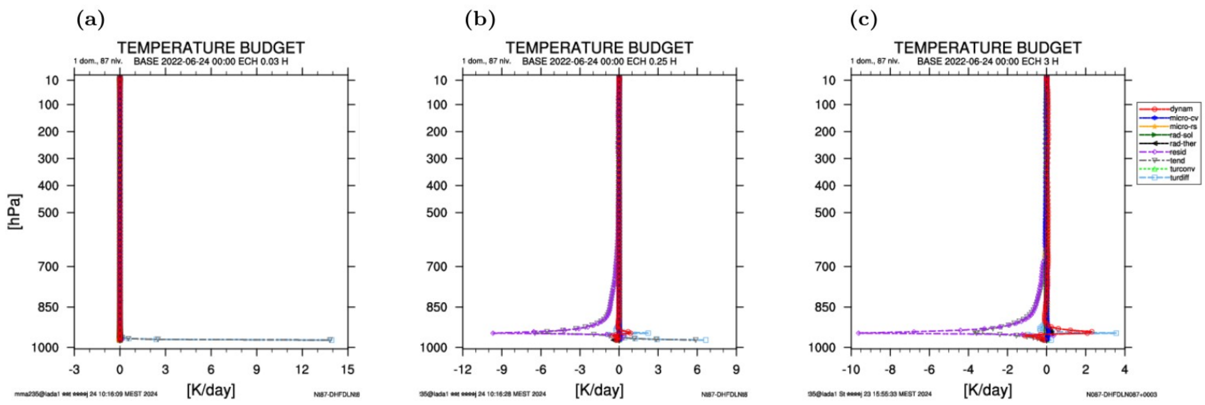

Fig. 11: The differences in ALDIN-CZ model temperature budget (new code – reference) after: (a) 1 time step (90 s), (b) 10 time steps (15 min) and (c) 120 time steps (3 h).

The new code ensures a numerically stable 24-hour simulation but is not reproducible with the reference code in the KLEVTUR=KLEV case (Fig. 11). The differences originate from turbulence source terms for heat and moisture at the lowest model level. Further, even the reference yields non-reproducible results when the radiation flux update is extracted from **arp_ground_param.F90** subroutine to **aplpar.F90**, although used only in the latter. In the new code, this extraction is necessary to "hide" KLEV from turbulence subroutines. However, the new code also fails to reproduce the modified reference, indicating additional discrepancies. Debugging will continue in 2025.

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), 0.00 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: D. Deacu (At) 6.50 PM, J. Mašek (Cz) 3.75 PM, S. Schneider (At) 0.75 PM, P. Sekuła (Pl) 0.50 PM, G. Stachura (Pl) 5.00 PM, A. Šljivić (Cz) 5.25 PM, V. Tarjáni (Sk) 4.00 PM and H. K. Tóth (Hu) 0.50 PM; TOTAL: **26.25 PM**

Planned timeframe:

Planned deliverable: code modification, documentation updates

Status/description: ONGOING

Sub-action: Investigate a stable regime in surface and boundary layer with C-LAEF 1k

Contributors: D. Deacu (At) 6.50 PM

Efforts: 6.50 PM

Documentation, deliverable: short report

Status/description: ONGOING

This study aimed to reduce nocturnal warm bias in near-surface air temperature within C-LAEF1k in Alpine valleys by testing the impact of (i) lowering the maximum Richardson number for surface turbulent fluxes and (ii) different soil freezing scheme options.

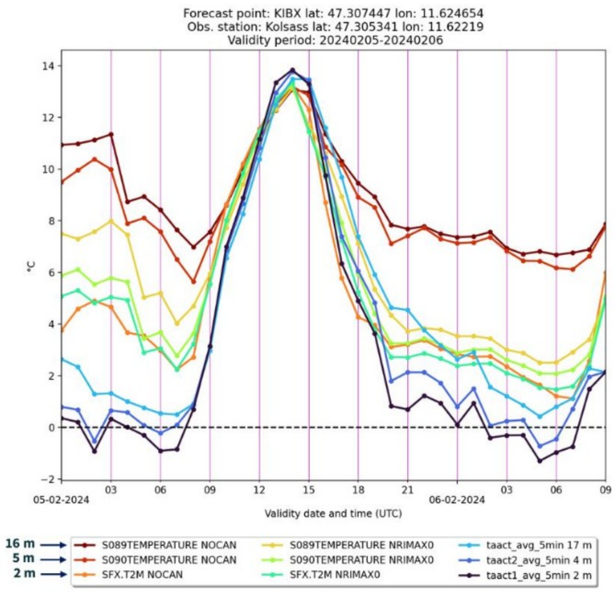

Fig. 12: The hourly air temperatures (averages of 1-min observed values over the preceding 5 min) observed at the i-Box Kolsass station (2, 4, and 17 m) and simulated at the nearest grid point at different heights (2, 5 and 16 m) for NOCAN (XRIMAX=0.2) and NRIMAX0 (XRIMAX=0.0) experiments.

Reducing XRIMAX (NRIMAX0; XRIMAX=0.0) increased transfer coefficients and turbulent fluxes, improving stable boundary layer simulations in the Inn Valley. While higher fluxes may not be more realistic, they could help to compensate for missing or inadequately represented grid-scale processes. Although 2-m temperatures were similar in both experiments (Fig. 12), NRIMAX0 experiment better matched observed temperatures at the I-Box Kolsass station compared to the reference NOCAN experiment (XRIMAX=0.2 and using control member of C-LAEF), especially at the lowest model levels. Comparable results were seen in 3-hour forecasts from assimilation cycles.

Daily soil freeze-thaw cycles in C-LAEF 1k linked to seemingly unrealistic deep-soil temperature (TG2 variable) variations, particularly in grass-covered grid boxes. To address this, the following soil freezing scheme experiments were conducted: (i) NOCANWGI0 (matches the control member of C-LAEF 1k), (ii) FRZDP (freezing/melting rates for the entire deep soil rather than for a shallow sub-layer), (iii) FRZDPLWT (FRZDP+soil freezing characteristic curve activated) and (iv) FRZDPKVEG1P5 (FRZDP+K_2 coefficient in the vegetation insulation coefficient reduced from 5 to 1.5).

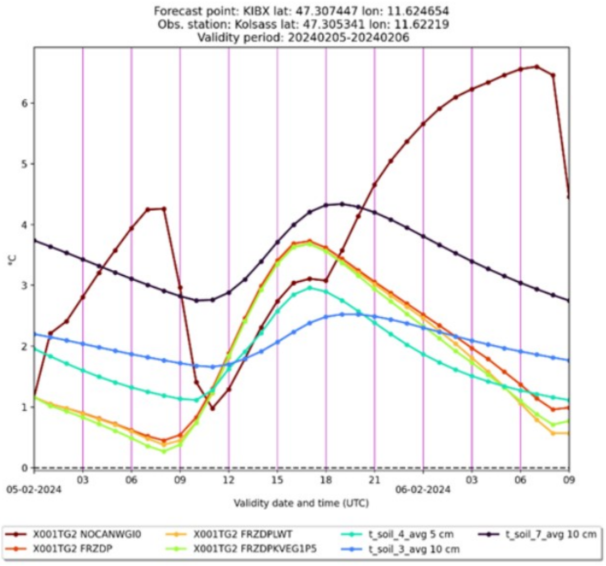

Fig. 13: Hourly soil temperatures observed at the i-Box Kolsass station and simulated at the nearest grid point. The deep-soil temperature (TG2) is shown for the NOCANWGI0, FRZDP, FRZDPLWT and FRZDPKVEG1P5 experiments. Soil temperatures were measured at two sites located 5 m apart: t_soil_3 and t_soil_4 were measured at one site at depths of 10 cm and 5 cm, respectively, while t_soil_7 was measured at the second site at a depth of 10 cm.

Primarily driven by freezing and thawing of soil ice in the surface soil layer, strong variations in the deep-soil temperature (TG2) are observed within the reference experiment (Fig. 13). What is particularly unusual is the high sensitivity of TG2 to these processes occurring in a just 1-cm thick surface layer, while the sub-surface layer remained ice-free throughout the integration. Despite increased production and melting of ice in the soil surface layer, the FRZDP experiment produced a more realistic variation of TG2 and a decrease in the night-time surface temperature (TG1) and consequently also in the 2-m temperature. The remaining two experiments further decreased TG2, TG1 and 2-m temperatures.

The results of this study are published in the ACCORD Newsletter 6 (see list of publications). The focus shifted towards changing the physiography from ECOCLIMAP-I to ECOCLIMAP-II and dealing with the problem of too high percentage of combined forest types on the floor of Alpine Valleys.

Sub-action: Debugging and testing ALARO with SURFEX

Contributors: J. Mašek (Cz) 3.75 PM, P. Sekuła (Pl) 0.50 PM, G. Stachura (Pl) 1.00 PM and A. Šljivić (Cz) 5.25 PM

Efforts: 10.50 PM

Documentation, deliverable: short report

Status/description: ONGOING

The focus was on the climate configuration and SURFEX 8.0+ version in the local CY46 model (14L diffuse ISBA, 12L explicit snow scheme, TEB and FLAKE). Several critical bugs were found and fixed, including (i) wind protection in the ECUME6 scheme (with TOUCANS), (ii) increased snow packing, (iii) FLAKE fix enabling safe restarts and iv) corrected calculation of canyon temperature in TEB (including deactivated traffic sources).

Further working with TEB, it was found that C_H calculated over the roofs was not done using the TOUCANS stability functions. Additionally, the ratio z_{0m}/z_{0h}=200 was used over the roofs, compared to z_{0m}/z_{0h}=1 for the canyon. The decision was made to follow the TOUCANS way and calculate C_H directly on the town scale, using the ratio z_{0m}/z_{0h}=10. The impact was positive but still not enough (Fig. 14; left vs. middle).

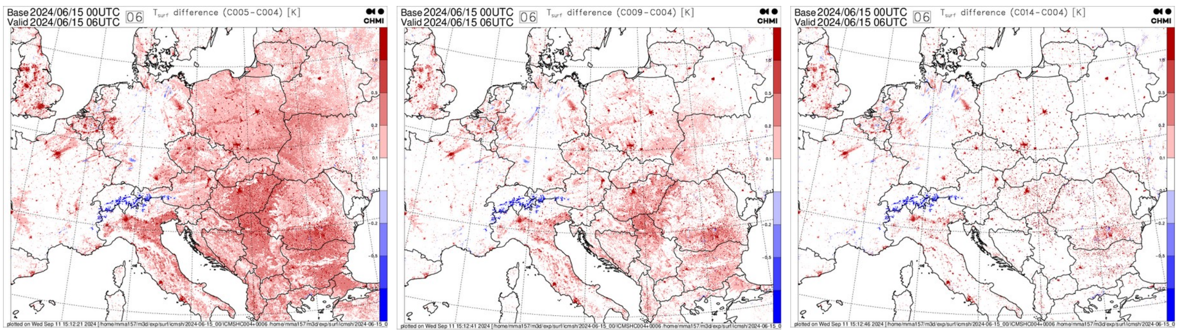

Fig. 14: The impact TEB on surface temperature with:(i) the starting version of the code (left), (ii) the correction to CH and z_{om}/z_{0h} computation (middle)and (iii) (ii) + filtering the points with town fraction < 5% (right).

The town fraction in ECOCLIMAP II was also inspected. It was found that large areas of Europe have a town fraction from 2 to 5%, which was highly suspicious. Following the correspondence with SURFEX support, it was suggested to keep ECOCLIMAP II but to filter town points with a too-small town fraction, i.e., convert it to nature in such points. Therefore, a tool to convert low town fractions in PGD file to nature was created. Applying the 5% threshold leads to results that seem more realistic (Fig. 14; right).

In addition, tests of the urban heat island started, pointing to the necessity of using the building energy model and possible tuning of heat capacity and thermal conductivity over roofs and walls. The screen level diagnostics in time-step zero was also improved, with ACTKECLS called after the SURFEX. Finally, a candidare configuration for NWP application was proposed:

- ISBA-FR scheme: option CISBA='3-L', 3 nature patches and no canopy
- ECOCLIMAP II dataset with filtered town fraction
- CALBEDO='CM13' albedo option (based on satellite retrievals)
- D95 snow scheme
- TEB with building energy model CCH_BEM='DOE-2', no urban canopy and LGARDEN=F;
- ECUME parameterization of sea fluxes (better with observations than ECUME6)
- FLAKE parameterization of lakes (yet to be validated, problems reported by MF).

Fixes for ALARO with SURFEX were moved to CY49T2 (contains SURFEX 8.1+), thus enabling the future ECOCLIMAP SG use. The associated code contribution was submitted to CY49T2_bf. However, integration into IAL code is pending due to a request to split commits for individual fixes. After SURFEX 9 becomes available, the above fixes also need to be submitted there.

During Gabriel Stachura's stay at CHMI, the snow treatment in TEB was addressed (see). Although snow from all surface tiles is accounted for during the integration, only the value from the nature tile is stored in the total snow field in an atmospheric mode (SURFRESERV.NEIGE). This research aimed to add snow from urban areas (calculated within the TEB model). Snow in town can occur on building roofs, impervious surfaces (roads) and gardens (if LGARDEN=.T.).

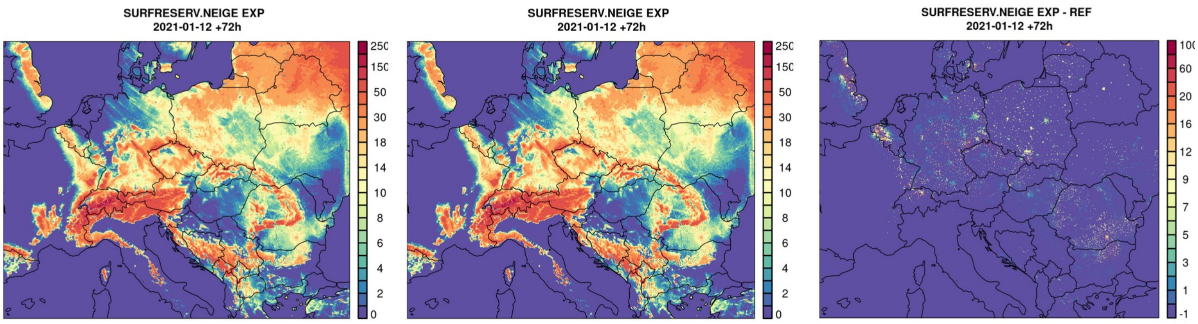

Fig. 15: The spatial distribution of snow water equivalent [kg/m²] in reference (left) and experimental (centre) runs, and their difference (right).

Code modifications encompassed 15 subroutines (see associated report for details). They can be turned on through the LSURF_MISC_BUDGET key in NAM_DIAG_TEBn. The comparison of total Snow Water Equivalent (SWE) in SURFEX and atmospheric files raised suspicion that arrays WSN_RF1 and WSN_RD1 carry SWE per town area, i.e., not per grid box area (as supposed), which should be clarified.

The first results indicated erroneous snow accumulation in places with little town fraction (< 5%), which was removed after transforming these points into the nature tile. Additionally, the differences compared to the reference experiment are observed in towns, while elsewhere, they remained the same (Fig. 15).

Finally, during Piotr Sekuła's stay in Prague (December), the impact of ALARO+SURFEX with TEB, including the choice of the snow scheme, the building energy model and the number of patches was addressed. The first tests on 3-day winter and summer periods indicate that (i) ALARO+SURFEX with TEB does not experience any fatalities, (ii) the impact of the snow scheme is dominant in the winter period and (iii) the impact of TEB on urban heat island in summer is small. More details will follow in a related report.

Sub-action: Town fraction-related experiments at HMS

Contributors: H. K. Tóth (Hu) 0.50 PM

Efforts: 0.50 PM

Documentation, deliverable: short report

Status/description: ONGOING

After the above findings at CHMI and the forecaster's reports on considerable warm biases in anticyclonic conditions within AROME/HU and AROME-EPS 2-m temperature forecasts (non-uniformly), the colleagues at Hungarian Met Service (HMS) conducted experiments with the corrected town fraction in ECOCLIMAP-II. A Fortran program prepared by Ján Mašek was used to modify the PGD file by converting urban tiles below the chosen threshold (FTOWN_MIN=0.05) to natural land cover.

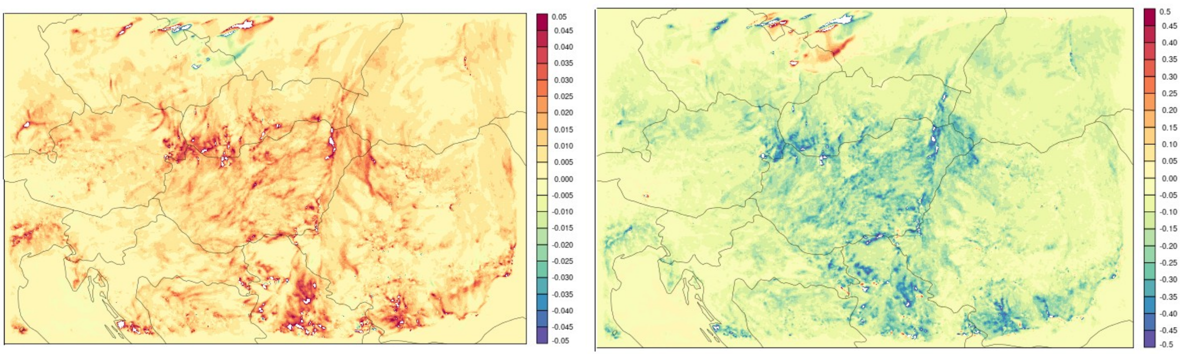

Fig. 16: Difference of 2-m rel. humidity (%; left) and temperature (°C; right) between the 18-h forecasts of AROME/HU using operational and modified setups, initialized at 00 UTC 19 June 2024.

The case study on 19 June 2024, using AROME/HU CY 43T2_bf11, pointed to decreased overestimation of evening temperatures (above 30°C) in southern and southeastern Hungary, with also cooler and more humid nights (Fig. 16). During a monthly summer period, including various weather conditions, the positive impact diminished. Currently, the modified town fraction configuration is being tested within the e-suite and will become operational if a neutral to positive influence is kept.

Sub-action: Testing snow schemes in SURFEX

Contributors: G. Stachura (Pl) 4.00 PM

Efforts: 4.00 PM

Documentation, deliverable: short report

Status/description: ONGOING

At IMGW, Gabriel Stachura evaluated the performance of all available snow schemes in the SURFEX model, i.e., D95, ESS, EBA and CROCUS. The forcing was taken from the local AROME configuration, while multi-layer snow schemes (ESS and CROCUS) were launched on ten vertical levels. TEB was turned off. The longer-term evaluation is performed for two Polish stations: (i) a mountain station SBSL (in the south), and (ii) a flat terrain station Souwalki (in the northeast). Except for EBA, all schemes tend to accumulate snow excessively, while the biggest relative differences were observed within several melting periods (Fig. 17; left). A more detailed analysis was performed during one such period (in December).

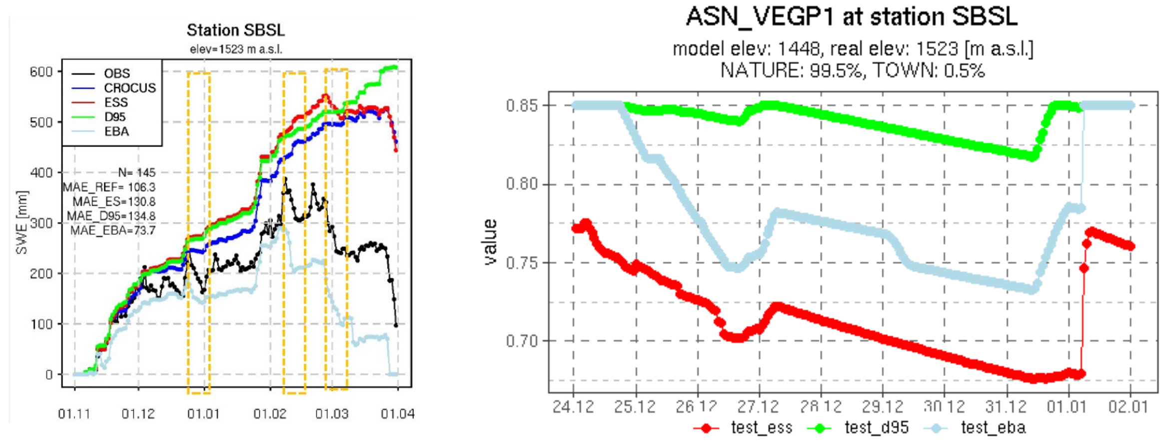

Fig. 17: The snow water equivalent (left)
and albedo (right) for station SBSL from experiments with different snow schemes. Yellow rectangles highlight the melting periods, and the albedo is shown for the first period.

It was found that despite a considerable increase in the forcing (warming in the lower troposphere), there was no decrease in the snow mass within D95 and ESS schemes (only in EBA). This is because the snow temperature, i.e., a composite soil–vegetation–snow surface temperature over nature tile for D95 and EBA, cannot reach 0 °C. The situation progressively worsens in the D95, which is related to the albedo (Fig. 17b; right) and a self-reinforcing feedback mechanism where: (i) a snowfall at the beginning of the analyzed period makes the albedo as high as possible, (ii) a high albedo results in less radiation penetrating the snowpack (snow temperature does not increase) and (iii) the albedo decreases rather slowly while melting is considerably delayed (or missing; appears in reality). Regarding the differences between schemes, it should be noted that melting depends on the surface temperature, and D95 is overall the coldest. Additionally, the decrease in albedo is exponential during the melting (linear otherwise), i.e., enhanced. Finally, in the EBA scheme, the impact of LAI on albedo is accounted for.

Although the scores highlight the EBA scheme as the most successful, caution is needed as it was never thoroughly validated. Further, snow density in EBA is constrained to 300 kg/m^3, which is insufficient for mountainous areas and can also contribute to easier melting. It is also hypothesised that the good performance of the EBA scheme is caused by a warm bias in surface temperature, which neutralizes the overestimation of snowpack observed for other snow schemes. Given the consensus within the ACCORD community that ESS is the most appropriate snow scheme, future research aims to study the impact of the forcing on its performance.

Finally, an external tool to initialize the ES scheme, i.e., to split the integral snow cover into multiple layers, has been developed. However, the ACCORD Surface Team recommended addressing this within the SURFEX environment (using FullPOS-PREP). Consequently, the related activities will be reorganized in that direction.

Sub-action: Investigating numerical oscillations in the surface energy balance solver

Contributors: V. Tarjáni (Sk) 4.00 PM

Efforts: 4.00 PM

Documentation, deliverable: short report

Status/description: ONGOING

At SHMU, Viktor Tarjáni investigated numerical oscillations in the surface energy balance (SEB) solver. Therein, he utilized the offline SURFEX and worked with explicit and Crocus snow schemes. The numerical oscillations were found in multiple variables, i.e., at screen level, in snow and soil or even the surface fluxes. However, they originate from the surface layer of the snowpack, penetrating to its deeper layers and eventually into the soil. The oscillations result from the numerical treatment of latent and sensible heat terms in the SEB solver, wherein only the first can lead to an unstable solution. On a heuristic basis, a few alternatives to the original scheme were proposed, including the one based on the tangent linear approximation, resulting in improved stability estimated using a stand-alone tool emulating the explicit snow scheme (Fig. 18). The evaluation and search for an improved numerical scheme will continue.

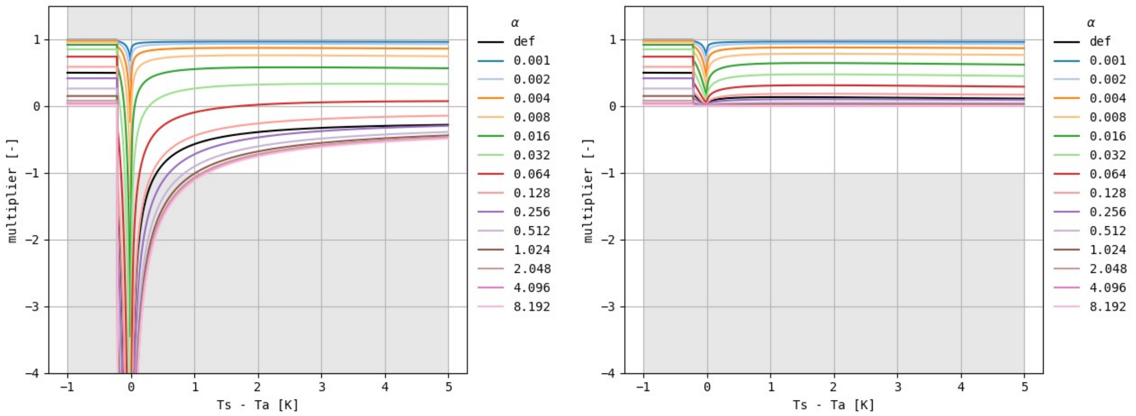

Fig. 18: Linear multiplier as a function of the difference between surface and forcing temperature for various values of universal parameter $\alpha=\Delta t/(\rho_s c_s \Delta z)$ for: (i) the original numerical scheme (left) and (ii) the tangent linear numerical scheme (right). ρ_s and c_s are the density of the snow surface layer and the specific heat of the snow, respectively.

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: J. Mašek (Cz) 0.50 PM; TOTAL: **0.50 PM**

Planned timeframe:

Planned deliverable: code modification, documentation updates

Status/description: ONGOING

At CHMI, Jan Mašek developed a tool to filter town fraction in PGD file, i.e., to correct the ECOCLIMAP-II town fraction data. This tool was later also used in other CMCs (see SU3 and associated efforts at HMS).

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);

- 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: B. Wibmer (At) 1.50 PM; TOTAL: **1.50 PM**

Planned timeframe:

Planned deliverable: code modification, documentation updates

Status/description: ONGOING

The HR package includes various contributions, such as dynamics and initialization oriented. Here, only physics-related aspects are included.

Sub-action: AROME thermally-driven wind studies

Contributors: B. Wibmer (At) 1.00 PM

Efforts: 1.00 PM

Documentation, deliverable: stay report and code

Status/description: ONGOING

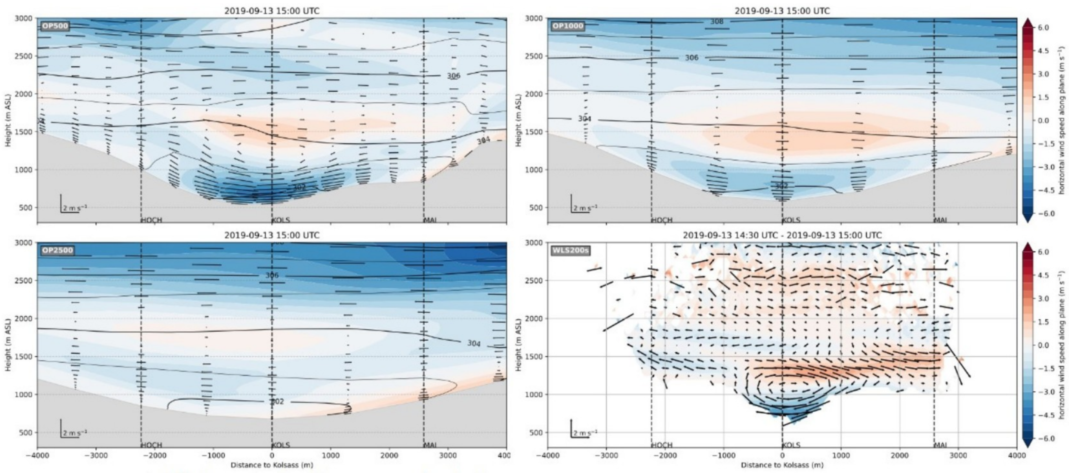

Fig. 19: Vertical cross-section through the Inn Valley and structure of related flow at: (i) dx=500 m (upper left), (ii) dx=1 km (upper right), (iii) dx=2.5 km (bottom left), iv) from ground-based LIDAR (bottom right).

Under the supervision of Clemens Wastl, Benedikt Wibmer 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. 19).

The research continued, focusing on the IOP8 case of 13th and 14th September 2019. Therein, the challenges with the nocturnal down-valley wind phase (underestimated) and persistent upvalley wind at ~ 1000 m (during the second night) were identified. Related to the first, there is insufficient thermal forcing, while forced channelling effects are likely underestimated. The improvements with higher resolution are small. Concerning the latter, i.e., persistent up-valley wind, there are problems with the thermal forcing that does not change the sign and forced channelling effects with NE-directed flow towards the Inn Valley entrance region. More details can be found in the presentation given at the 4th ACCORD All Staff Workshop.

Sub-action: Evaluation of stratus forecasts in Inn Valley

Contributors: B. Wibmer (At) 0.50 PM

Efforts: 0.50 PM

Documentation, deliverable: stay report and code

Status/description: ONGOING

The problems in AROME and C-LAEF 1k in capturing low stratus events in inner Alpine areas were observed. By rerunning C-LAEF 1k, Benedikt Wibmer investigated 4 cases from the past winter, 3 in the Inn Valley and 1 in Carinthia (southern Austria). The performance strongly depends on the initial conditions, i.e., when assimilating additional ceilometer data, the fog in the first hours of the forecast is produced but dissipates too fast. The valley atmosphere is too dry and warm (in the model), and too strong mixing is observed. The increase in resolution (from 2.5 to 1 km) does help in some cases (2.5 km is too coarse to resolve the valleys), but the problem with the too-dry valley atmosphere stays the same. In future, the impact of increased vertical resolution will be investigated.

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: NONE, **0.00 PM**

Planned timeframe:

Planned deliverable: code modification, documentation updates

Status/description: PENDING

3 Documents and publications

List of reports:

Ana Šljivić and Ján Mašek, 2024: Producing new CAMS aerosol input for climate files, CHMI technical document, Prague.

Ana Šljivić and Ján Mašek, 2024: Vertical distribution of climatological aerosols, CHMI research note, Prague.

Daniel Deacu, Clemens Wastl and Christoph Wittmann: Addressing the Warm Bias of the Nocturnal Near-Surface Air Temperature Forecasts of C-LAEF 1k in Alpine Valleys, GeoSphere Austria research report, Vienna 2025.

David Němec, 2024: Playing around with the gamma distribution, CHMI research note, Prague 2024

David Němec, 2024: Towards double-moment parameterization of rain, ACCORD flat-rate stay, Ghent, 02.09.2024-20.09.2024.

Gabriel Stachura: Adding snow from town to total snow in an atmospheric model & initialization of explicit snow scheme in coupled ALARO-SURFEX, ACCORD flat-rate stay, Prague, 19.08.2024-31.08.2024.

Peter Smerkol, 2024: Bug correction in the ACDIFV3 routine, RC-LACE stay, Prague, 12.05.2024.-08.06.2024.

Piotr Sekuła and Ján Mašek, 2024: Use of CAMS atmospheric aerosols in AROME/HARMONIE-AROME/ALARO, technical document. (https://redmine.umr-cnrm.fr/attachments/download/6098/Technical_document_CAMS_description.pdf)

List o scientific papers:

Nemec, D., Brožková, R., & Van Ginderachter, M. (2024). Developments of Single-Moment ALARO Microphysics Scheme with Three Prognostic Ice Categories. *Tellus A: Dynamic Meteorology and Oceanography*, *76*(1).

Hrastinski, M., Mašek, J., Bašták Ďurán, I., Grisogono, B., Brožková, R. (2024): Regime-dependent turbulence length scale formulation for NWP models based on turbulence kinetic energy, shear and stratification (in revision at *Monthly Weather Review*)

Deacu D., Wastl, C. and Wittmann, C., Reducing the Nocturnal Warm Bias in C-LAEF 1k Simulations for Alpine Valleys, *ACCORD Newsletter*, **6**, 81–87, 2024.

4 Activities of management, coordination and communication

Gathering reports on the work done from Q1 to Q4 and planning research stays/activities in 2025. Participating in the "Task Team for the Model Forecast" for the ACCORD strategy 2026-2030 preparation. Preliminary correspondence on the organization of ALARO-1 Working Days and ALARO+SURFEX training.

5 Research stays

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

- Debugging the Third-Order Moments (TOMs) solver in the TOUCANS scheme – Peter Smerkol (4 weeks, CHMI, Prague)
- The adaptation of the TOUCANS code to differentiate the number of vertical levels as seen by turbulence and dynamics – Mario Hrastinski (2+2 weeks, CHMI, Prague)
- Study CAR interactions – Piotr Sekuła (4 weeks; CHMI, Prague)

Two ACCORD DAP supported stay were executed (7 weeks in total[1]):

- TEB and snow related developments – Gabriel Stachura (2 weeks, CHMI, Prague)
- Development of the two-moment microphysics scheme in the ALARO-CMC – David Němec (3 weeks, University of Ghent)
- Testing different options within TEB (taken over from Gabriel Stachura) - Piotr Sekuła (2 weeks, CHMI, Prague)

1 Originally, it was supposed to be 4 weeks, but Gabriel asked to shorten it to 2 weeks for personal reasons. It was agreed that Piotr Sekuła will execute the remaining two weeks.

6 Summary of resources

Summary of resources for the year 2024 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*	19.25*	2.00	2.00	0.00	0.00
PH2: Radiation	1.50	0.25	0.00	0.00	0.00	0.00
PH3: Clouds-precipitation microphysics	10.50	9.25	0.00	0.00	0.75	0.75
PH4: Common 1D MUSC framework for parametrization validation	2.00	0.75	0.00	0.00	0.00	0.00
PH5: Model Output Postprocessing Parameters	4.50	3.25	0.00	0.00	0.00	0.00
PH6: Study the cloud/aerosol/radiation (CAR) interactions	13.50	6.75	1.00	1.00	0.00	0.00
PH7: On the interface between the surface and the atmosphere	11.50	2.50	0.00	0.00	0.00	0.00
PH8: On the interface of Physics with Dynamics (and time stepping)	0.00*	0.00*	0.00*	0.00*	0.00	0.00
SU3: SURFEX: validation and development of existing components for NWP	15.00	26.25	0.00	0.00	1.00	1.00
SU5: Assess/improve quality of surface characterization	4.00	0.50	0.00	0.00	0.00	0.00
HR: Sub-km modelling	4.50*	2.50*	0.00*	0.00*	0.00*	0.00*
SPTR: Addressing future evolutions of software infrastructure	2.50	0.00	0.00	0.00	0.00	0.00
TOTAL	80.50	71.25	3.00	3.00	1.75	1.75

(*) 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., (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.

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.

Rotach, M., Stiperski, I., Fuhrer, O., Goger, B., Gohm, A., Obleitner, F., Rau, G., Sfyri, E. And Vergeiner, J., 2017: Investigating Exchange Processes over Complex Topography: The Innsbruck Box (i-Box). *Bull. Amer. Meteor. Soc.*, **98**, 787–805. DOI: 10.1175/BAMS-D-15-00246.1.