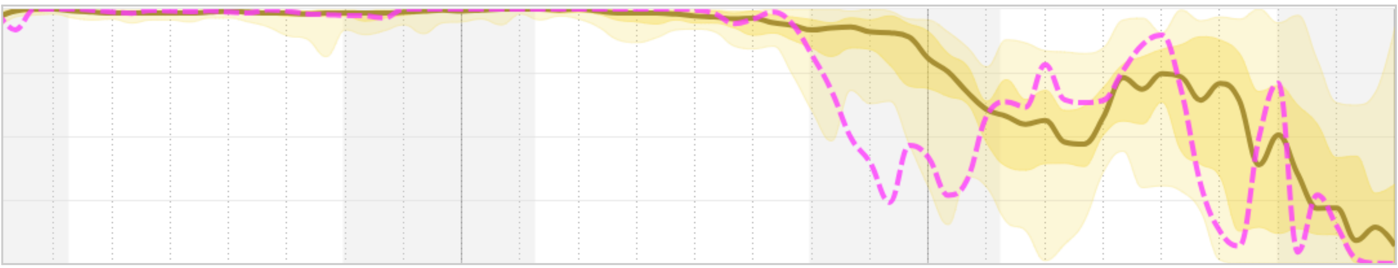
Report on stay at CHMI

07/01~19/01, 2024, Prague, Czech Republic

Upgrade and validation of A-LAEF multiphysics based on the latest ALARO-1 code at cy46t1



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::Acknowledgements

I would like to express my sincere gratitude to Jan Mašek, whose guidance and expertise were invaluable throughout my stay. I am also deeply thankful to Radmila, Alena and David for their support and insightful discussions. Last but not least, I would like to thank the whole Prague's team for their hospitality, for providing me with the real family atmosphere during my short stay.

::Foreword

A-LAEF is ALARO CSC based regional ensemble forecasting system, running as a Time Critical-2 (TC2) application on HPCF at ECMWF (Belluš, Tudor, Abellan, 2022). It is being developed by SHMU within the cooperation of the RC LACE consortium. The operational runs of the A-LAEF TC2 application are funded with the SBUs provided by Slovenia, Croatia and Turkey (full ECMWF members). It consists of 16 perturbed ensemble members and one unperturbed control run, supplying forecasts twice a day for the next 72 hours, covering the area exceeding the boundaries of the European continent. It has been used in operations by LACE partners and Turkey since 2019. A-LAEF successfully predicted many extreme weather situations within Europe, and it provides quality probabilistic forecasts on a daily basis. The latest technical upgrade of the A-LAEF system was done during its migration to the new ECMWF HPCF in Bologna (Atos) in November 2022, which was quite a challenging task also due to the given time constraints. Therefore, that particular moment was not suitable for upgrading the model cycle (and physics).

Except for the quality of forecasts, one of the crucial features of such a system is its stability and reliability. From this perspective, the formerly used model cycle cy40t1 had literally no issues and exhibited only 1 or 2 crashes due to physics within the whole period of its utilisation (over the 4 years). Nevertheless, it lagged some new technical features and missed new prognostic/diagnostic fields interesting for the customers and forecasters. Hence, the upgrade of the A-LAEF system to model cycle cy46t1 has been initiated at the end of 2023.

During this 2-week stay in Prague the upgrade of A-LAEF multiphysics based on the latest ALARO-1 code development at model cycle cy46t1 was prepared and tested. The two physics clusters were derived from CZ operational and double suite, incorporating different tunings and parameterizations. Their ability to produce distinct weather scenarios was verified. As a next step, these two clusters were further expanded by other two configurations - using a different mixing length parameterization (the code for EL1 on cy46t1 was not ready during the stay, so this part of the work was subsequently finished locally in Bratislava). In order to improve the overall model uncertainty simulation, the stochastic perturbation of ISBA surface prognostic fields was phased into cy46t1 too and validated. The combination of 4 new physics clusters with the stochastic physics perturbation was tested as a whole new model uncertainty simulation, giving reasonable and comparable results to those of the operational outputs (based on the model cycle cy40t1).

A significant upgrade is the presence of prognostic graupel, which was missing in the ALARO physics until now. It enables more realistic simulation of intense convection, with the impact on other meteorological fields (e.g. wind gusts and simulated radar reflectivity). New code used in the A-LAEF system also includes diagnostics of 16 distinct precipitation types, flashes, and wet snow diagnostics with its accretion on high voltage wires (by André Simon). New probabilistic maps for precipitation types were prepared and tested during a freezing rain event in south-western part of Slovakia, successfully predicting the timing and spatial localization of the phenomena. Finally, new climatological files for the A-LAEF domain were prepared with the updated orography related fields, including their low spectral truncation version for the upper-air blending. This enhancement is anticipated to improve the representativeness of surface fields. However, it has not been tested in the new A-LAEF system yet, as it falls well beyond the scope of this 2-week stay.

::I New ALARO-1 multiphysics

To begin with, the two main physics clusters were derived from the CZ operational and double (candidate) suite, including different tunings and parameterizations. The most important difference between those two setups lies in the changes regarding the evaporation and related microphysics. The Lopez evaporation scheme, which is more aligned with physical fundamentals, is used in the half of the ensemble instead of the Kessler scheme (while Kessler is still being kept in the second half of the members).

The aim of exploiting the Lopez evaporation is to reduce the overall overestimation of precipitation (but also to reduce the precipitation maxima in convective situations), improve representation of rain shadow, and reduce cold bias of temperature. It comes together with the adjustments of clouds in radiation, microphysics and condensation.

Further modifications have been made to the flash diagnostics and precipitation type settings. Diagnostic precipitation type (16 different species) has been introduced into the code by Meteo France some years ago. It is based on the vertical profile of wet bulb temperature and the amount of predicted rain, snow and graupel precipitation. Two diagnostic fields are actually available, one with the most frequent precipitation type and the other one with the most severe type in a given time period (two time periods can be defined via model namelist).

A new approach to account for the impact of snow on roughness length is included within the package too, alongside with a recalibration of snow fraction, aimed at mitigating cold bias in screen level temperature.

These two main physics configurations were adapted for the A-LAEF domain, spatial resolution, and changed for hydrostatic dynamics, which is still sufficient at the 4.8 km mesh size used in A-LAEF. Their ability to produce reasonably distinct weather scenarios was tested and the results are shown in figure 1. To limit the impact solely to the physics configurations, the experiments were conducted using the identical INIT and LBC files (involving no perturbation sources).

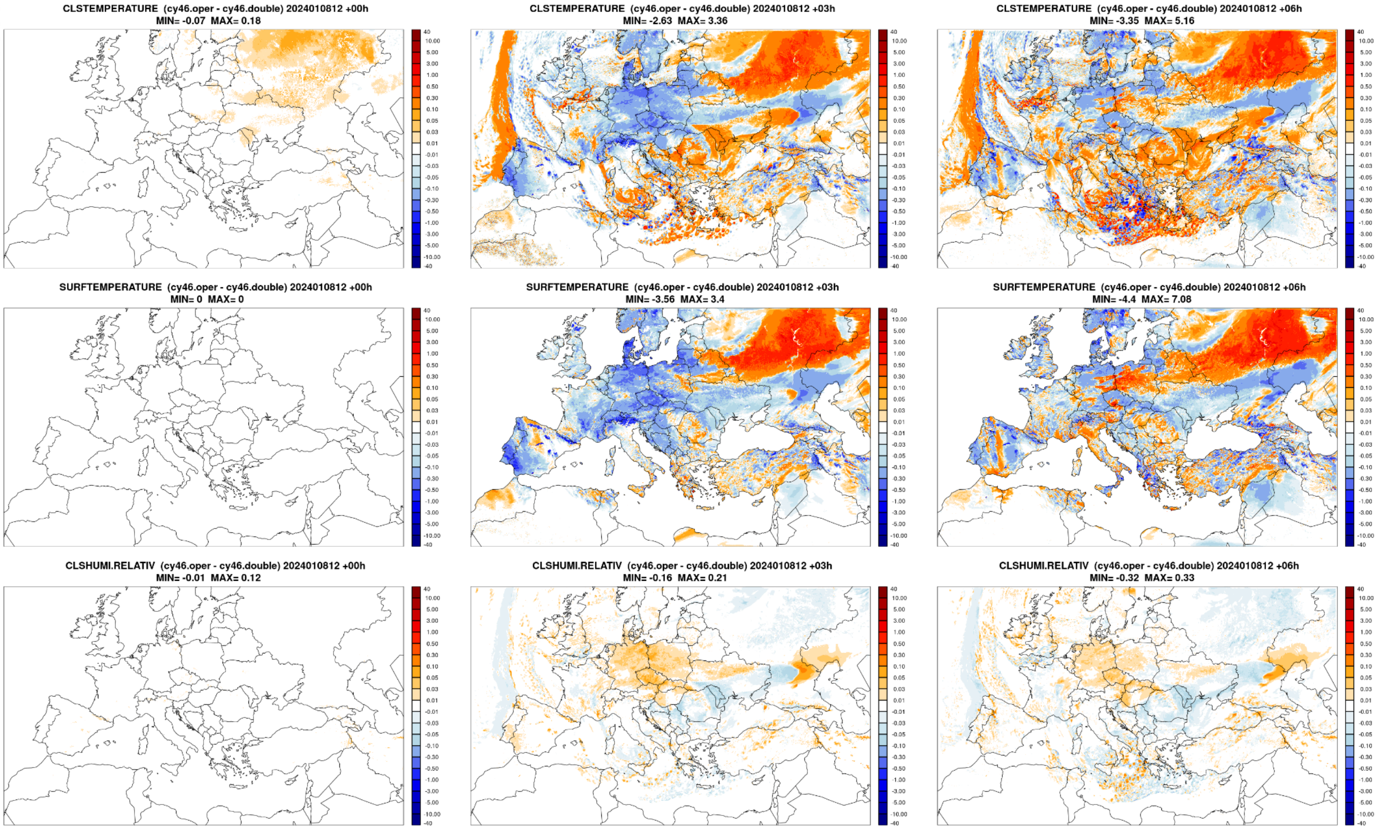

Fig.1: *Difference between two main physics configurations in A-LAEF forecast after +00, +03 and +06 hours of integration (from left to right). The maps of T2m are shown in the first row, surface temperature in the second row, and RH2m in the third row.*

The reader may notice small differences in T2m (RH2m) fields already at the analysis time (+00 output) in figure 1. These are caused by the screen level diagnostics due to a different snow fraction value (WCRIN) entering the gridbox roughness calculation.

Another two physics variations were constructed by the combination of different mixing length computations - EL0 (Geleyn-Cedilnik) and EL1 (revised Bougeault-Lacarrère with the inclusion of a shear term). Each of them is associated with the calculation of the Planetary Boundary Layer (PBL) height using the weak capping inversion method and the TKE-based method, respectively. In principle, we do not know of any single method which would accurately estimate the PBL height for different stability conditions. The first method might be better for convective and near-neutral stratification, while the latter is more general. Therefore, those two configurations are good candidates for inflating the ensemble spread and to cover a wider range of real situations at the same time (possibly allowing for the capturing of extreme weather too). The impact of EL1 vs EL0 configuration is shown in figure 2.

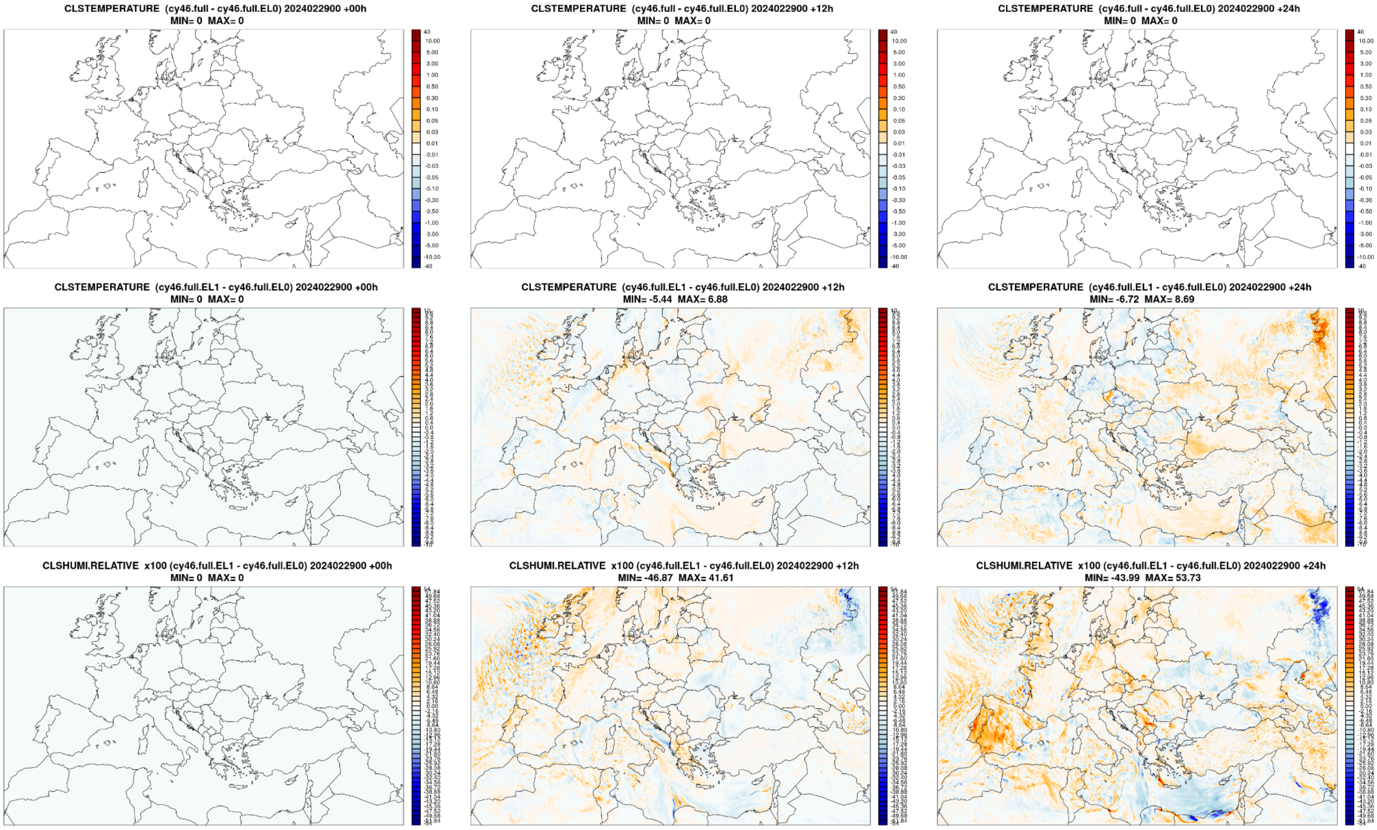

Fig.2: *Difference between EL1 and EL0 configurations in A-LAEF forecast after +00, +12 and +24 hours of integration (from left to right). T2m in the first row is just a validation of the code upgraded with the EL1 modset (but keeping the EL0 settings) => hence no difference. In the second row we see the impact for T2m, and in the third row for RH2m.*

In conclusion, we constructed 4 different physics setups (phys01..04), as they are summarised in table 1. Different physics parameterizations and tunings are applied to the precipitation types, mixing length choice, PBL height computation and related TUCANS tuning, choice of evaporation scheme, roughness impact of snow via snow height, critical humidity profile tuning for radiation cloudiness, autoconversion to rain and snow, flash diagnostics, variation of exponential-random cloud overlap in radiation, liquid/ice partition for cloud condensate, max. evaporation rate for rain, critical liquid water content for liquid cloud water autoconversion, ratio of mechanical roughness length to obstacle height, choice of wind diagnostics (TKE vs friction velocity), etc.

All the above content makes it currently the most relevant physics package regarding the state-of-the-art ALARO code, which might not be fully present even in the newly released cy49t1. It should be stressed that all setups originate in well tested and tuned configurations used (or meant to be used) in the NWP operations for the deterministic runs, which makes this kind of model physics uncertainty simulation different from the nowadays widely used stochastically perturbed parameterizations (SPP). Nevertheless, it can obviously produce reasonable spread in the EPS context.

Tab.1: *New A-LAEF multiphysics configurations.*

cluster / member	phys01	phys02	phys03	phys04
	00,01,05,09,13	02,06,10,14	03,07,11,15	04,08,12,16
namelist parameter	oper	double	oper	double
	EL0		EL1	
RDHAIL1	2.8	2.4	2.8	2.4
RDHAIL2	7.5	6.5	7.5	6.5
CGMIXLEN	EL0	EL0	EL1	EL1
LPBLH_TKE	F	F	T	T
XMAXLM	0.	0.	5000.	5000.
ETKE_C0SHEAR	N/A	N/A	0.35	0.35
ETKE_DTHETA_S1	N/A	N/A	-2.5	-2.5
ETKE_DTHETA_S2	N/A	N/A	1.0	1.0
ETKE_R2SIM	N/A	N/A	0.1	0.1
LEVAPLOP	F	T	F	T
LZ0SNOWH	F	T	F	T
HUCREDRA	0.42	0.46	0.42	0.46
RAUTEFR	0.5E-03	0.8E-03	0.5E-03	0.8E-03
RAUTEFS	2.E-03	1.E-03	2.E-03	1.E-03
RCFLASH1	16.76	22.29	16.76	22.29
RDECRD1	10000.	8000.	10000.	8000.
RDECRD2	20000.	215000.	20000.	215000.
RDTFAC	1.00	0.75	1.00	0.75
REVASXR	0.	7.E-07	0.	7.E-07
RQLCR	3.E-04	4.E-04	3.E-04	4.E-04
WCRIN	4.0	10.0	4.0	10.0
RZ0_TO_HEIGHT	N/A	0.1	N/A	0.1
FACRAF	10.0	3.6	10.0	3.6
LRAFTKE	F	T	F	T
LRAFTUR	T	F	T	F

Few comments from the implementation and testing:

Performance - The integration with the new cy46t1 code and new settings is surprisingly about 30% faster in comparison with the older version based on cy40t1 code. This is of course very welcome bonus, not even for the sake of shortening the computations, but rather for the possibility to use those spared SBUs for something else (e.g. for prolongation of integration up to +78 hours to cover 3 full “hydrological” and “climatological” days, since this was already requested by forecasters).

Debugging - It was found that for the configuration LEXTERN=T, NFPGRIB=123, NFPOS=1 (grib production within the inline fullpos) the model was crashing. Fixing FASGRA routine solved this issue.

Instabilities A - At the very beginning some reproducible instability for one member (MEM_04) after +27 hours of integration occurred in one of our experiments. This instability was eliminated by turning off TOMS (LCOEFK_TOMS=.F.) - the TUCANS third order moments parameterization.

Instabilities B - While implementing EL1 mixing length parameterization, its sensitivity to the strong vertical gradients had to be addressed (according to Mario Hrastinski). This was treated by disabling APACHE interpolations (LESCALE_T/Q/U/PD/GFL=.F.) in c903 configuration, where the lateral boundary conditions are prepared. Such interpolations could possibly generate strong vertical gradients in coupling zone (e.g. above the lakes). An irreproducible crash (paradoxically for EL0 configuration and even with switched off APACHE interpolations) happened during the validation experiments. We concluded that this isolated and irreproducible crash was rather related to a sporadic HW/SW issue on Atos computer.

::II Surface stochastic physics

In order to enhance the overall model uncertainty simulation, the stochastic perturbation of ISBA surface prognostic fields was phased into cy46t1 and validated (see figure 3). At each time step in grid-point space, stochastic perturbations are applied to the physics tendencies of surface fields including surface temperature, surface liquid water content, surface frozen water content, snow albedo, snow reservoir water content, snow density, and water intercepted by vegetation (7 fields in total). Direct perturbations of deep soil prognostic fields, such as deep soil temperature or moisture, were deliberately avoided. They naturally undergo much slower temporal changes, exhibiting a delayed response compared to the surface.

The multiplicative noise applied to the physics tendencies is provided by a spectral stochastic pattern generator, which evolves over both time and space. Its behaviour is being controlled by the settings via the namelist. We kept the formerly tested and validated tuning for A-LAEF domain with standard deviation (sensitivity) 0.25, time correlation 2 h, and spatial correlation 500 km.

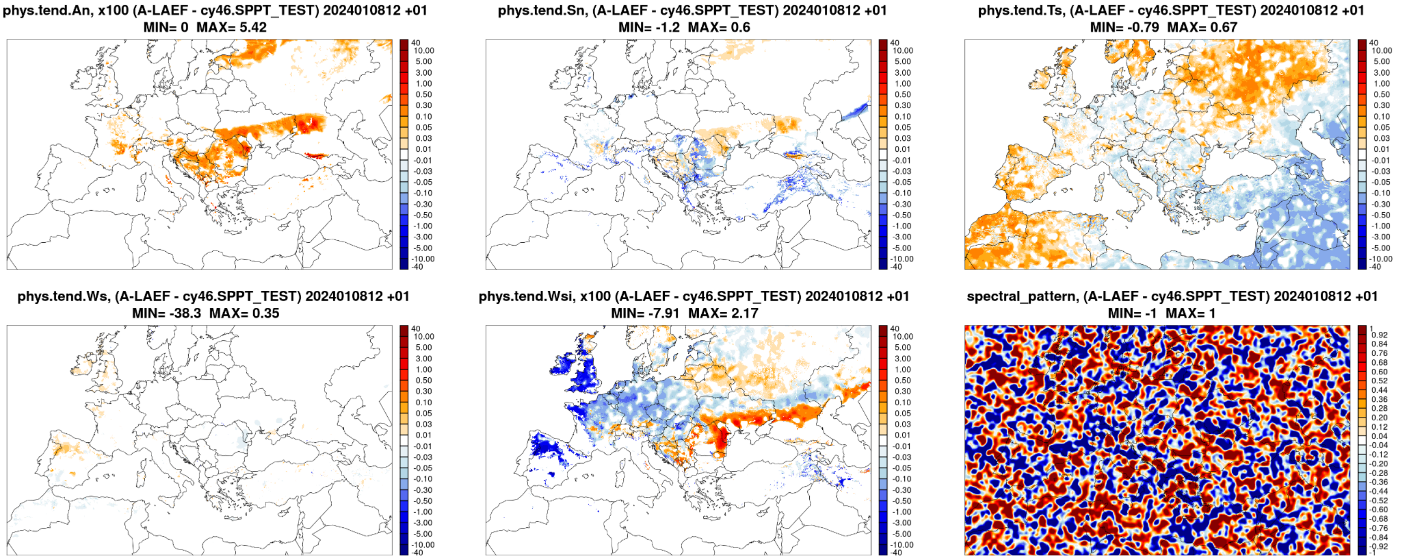

Fig.3: *Perturbed physics tendencies for selected ISBA prognostic fields. From the upper left to the bottom right: snow albedo, water in snow, surface temperature, liquid water, frozen water and the stochastic pattern (all valid for the lead time +01 h).*

::III Product delta analysis

In this chapter we are going to compare the first complete outputs of the upgraded A-LAEF system (with respect to the new ALARO multi-physics and model uncertainty simulation per se) with the operational products. We will try to give an initial answer to the fundamental question: How do the changes introduced in the physics parameterizations influence the predictive capabilities of the A-LAEF ensemble system? Although we certainly cannot give a complete answer to this question right here (based only on several very first complete runs), we will try to give at least some insights.

The differences in basic ensemble characteristics like mean, spread, minimum and maximum are rather small for the precipitation and wind fields (globally), while they can still be slightly diverse on local scales (see figures 5, 6 and 9). This is valid for the total cloudiness and short lead times too (see figure 4), while the spread for cloudiness expectedly increases for longer forecast ranges, having naturally a big uncertainty (not shown).

Such a trend (consistently comparable ensemble mean and slightly increased spread) is not observed for temperature at 2 m (T2m). While the ensemble mean of T2m is still quite comparable between the old and new system, the response of upgraded ALARO physics is definitely stronger here in comparison with the other meteorological fields. The extreme values within the ensemble members increased for T2m, and the spread of the ensemble got almost twice bigger (at least in the given test case and longer lead times, see figure 8). However, this effect is much less pronounced for shorter lead times (see figure 7).

The above characteristics can be observed also within a point forecast involving the time evolution of meteorological variables (see epsgrams in figure 10). Table 2 presents some simple statistics for this specific forecast, aligning well with the map-format outputs. Whether this can be considered as a systematic change (be it an improvement or worsening), we will see only after an objective verification for a longer period.

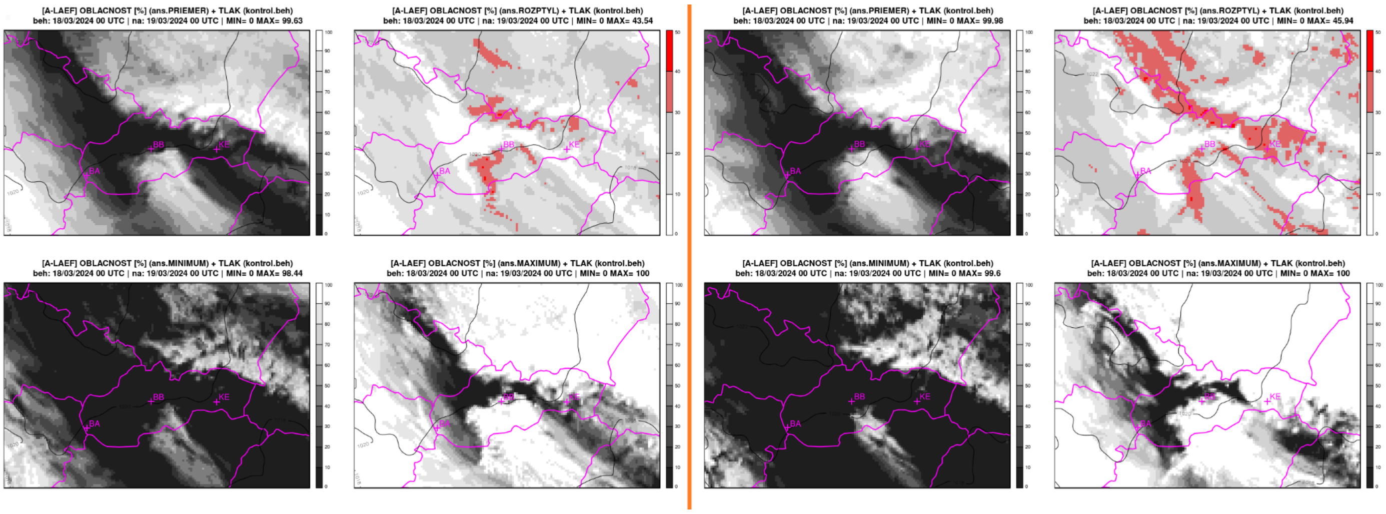

Fig.4: *Total cloudiness forecast (+24 h) - ensemble mean, spread, minimum and maximum of ensemble for the operational A-LAEF system at cy40t1 (left 4-panel) and for the new A-LAEF system at cy46t1 involving upgraded ALARO physics (right 4-panel). Zoom over Slovakia.*

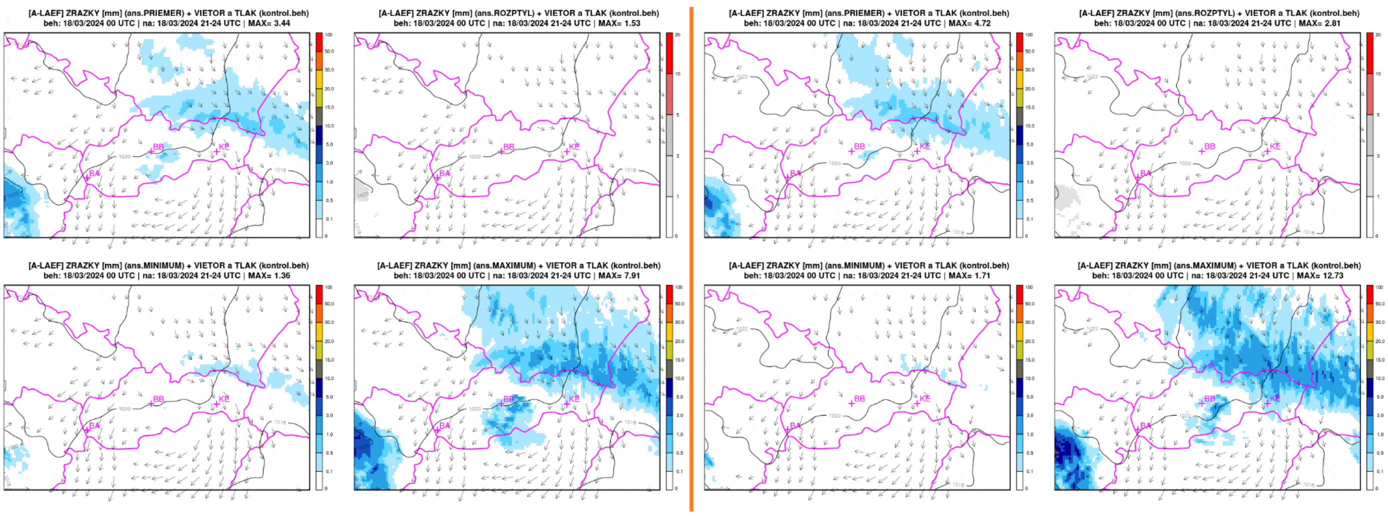

Fig.5: *Total precipitation forecast (+21-24 h) - ensemble mean, spread, minimum and maximum of ensemble for the operational A-LAEF system at cy40t1 (left 4-panel) and for the new A-LAEF system at cy46t1 involving upgraded ALARO physics (right 4-panel). Zoom over Slovakia.*

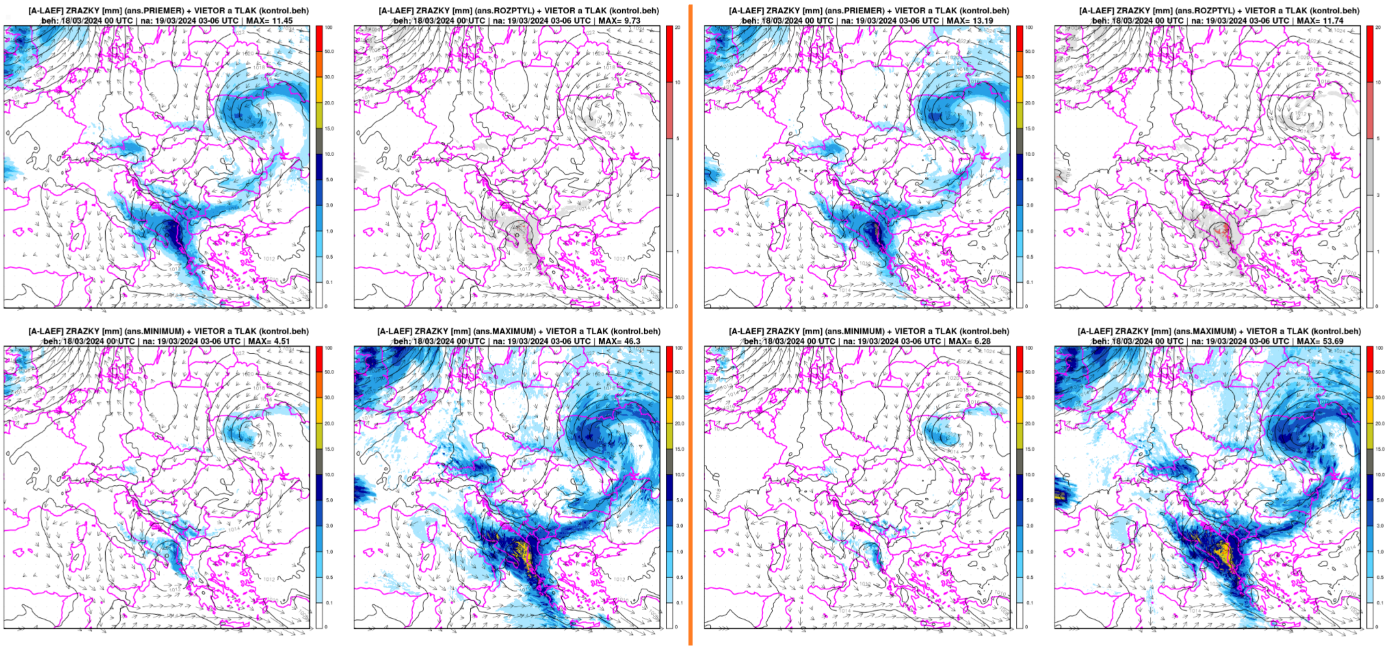

Fig.6: *Total precipitation forecast (+27-30 h) - ensemble mean, spread, minimum and maximum of ensemble for the operational A-LAEF system at cy40t1 (left 4-panel) and for the new A-LAEF system at cy46t1 involving upgraded ALARO physics (right 4-panel). LACE postprocessing domain.*

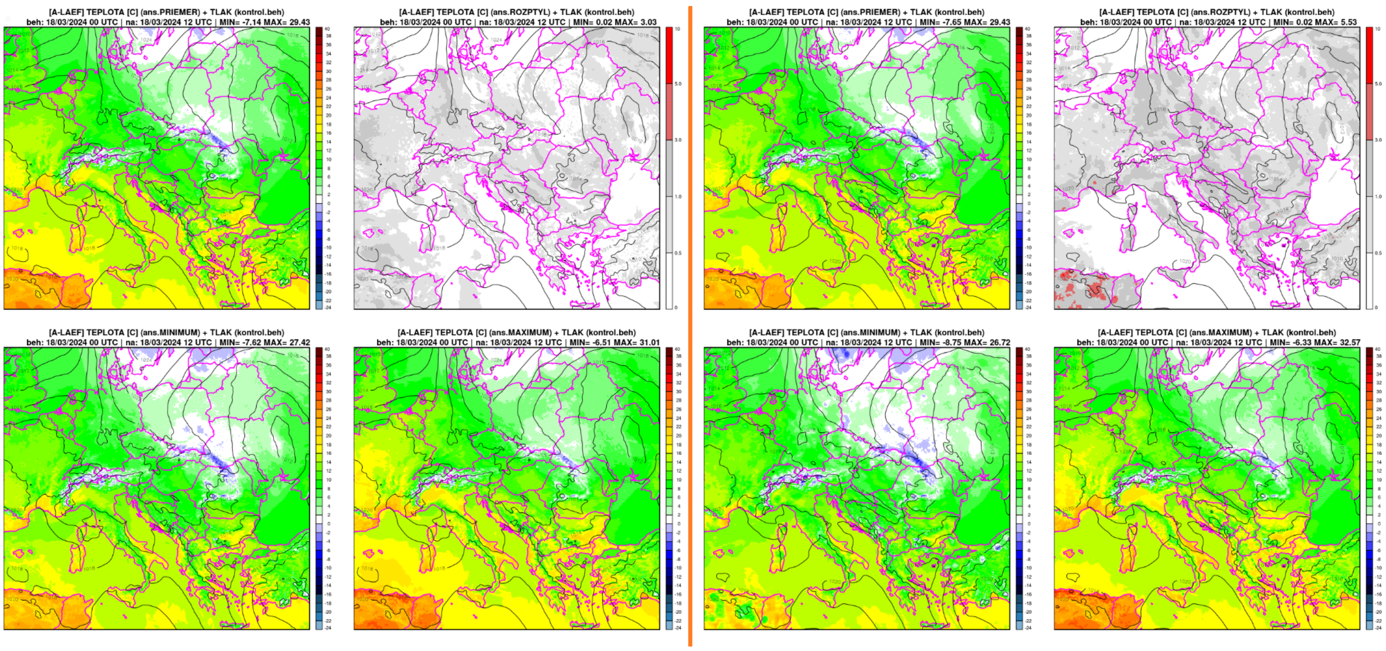

Fig.7: *Temperature at 2 m forecast for +12 h - ensemble mean, spread, minimum and maximum of ensemble for the operational A-LAEF system at cy40t1 (left 4-panel) and for the new A-LAEF system at cy46t1 involving upgraded ALARO physics (right 4-panel). LACE postprocessing domain.*

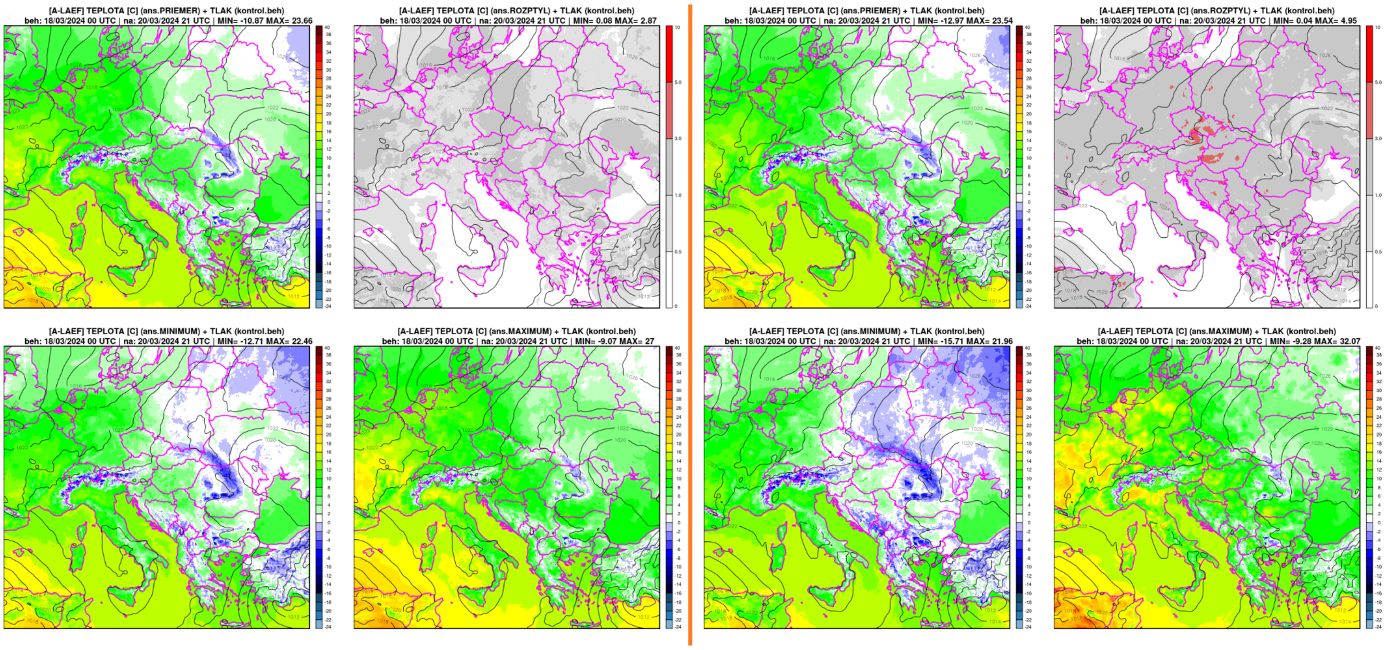

Fig.8: *Temperature at 2 m forecast for +69 h - ensemble mean, spread, minimum and maximum of ensemble for the operational A-LAEF system at cy40t1 (left 4-panel) and for the new A-LAEF system at cy46t1 involving upgraded ALARO physics (right 4-panel). LACE postprocessing domain.*

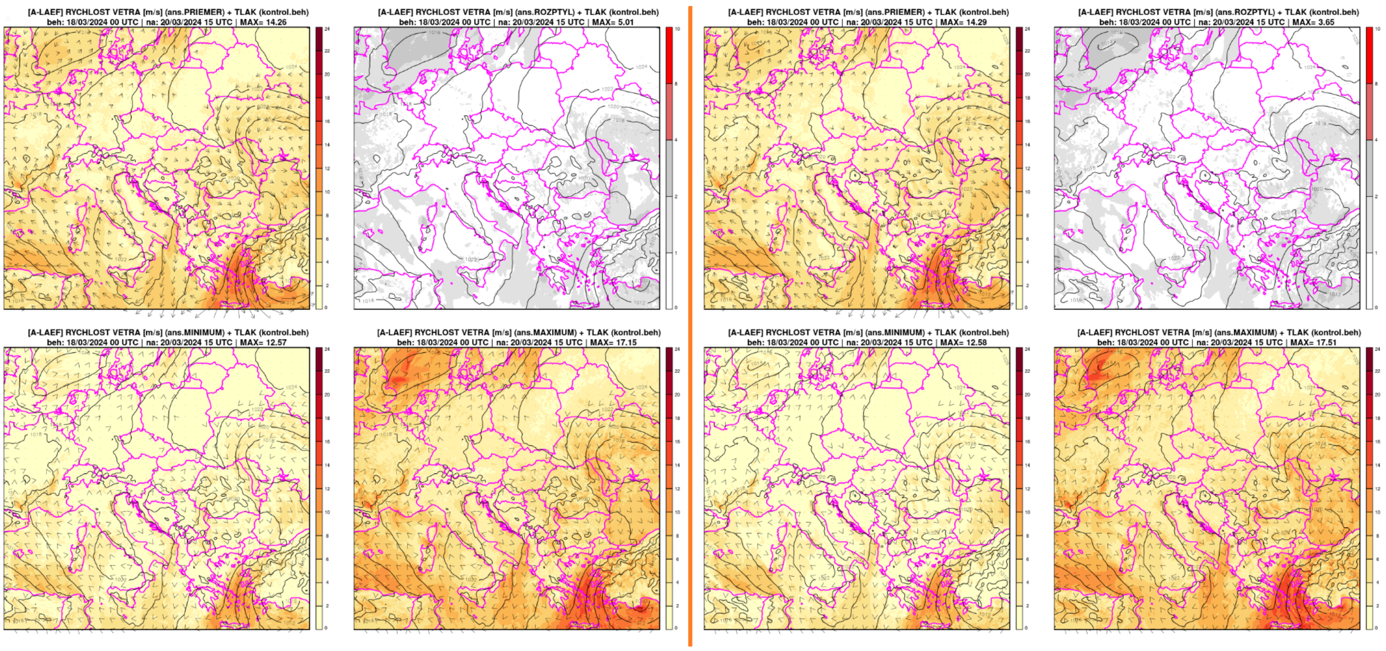

Fig.9: *Wind at 10 m forecast for +63 h - ensemble mean, spread, minimum and maximum of ensemble for the operational A-LAEF system at cy40t1 (left 4-panel) and for the new A-LAEF system at cy46t1 involving upgraded ALARO physics (right 4-panel). LACE postprocessing domain.*

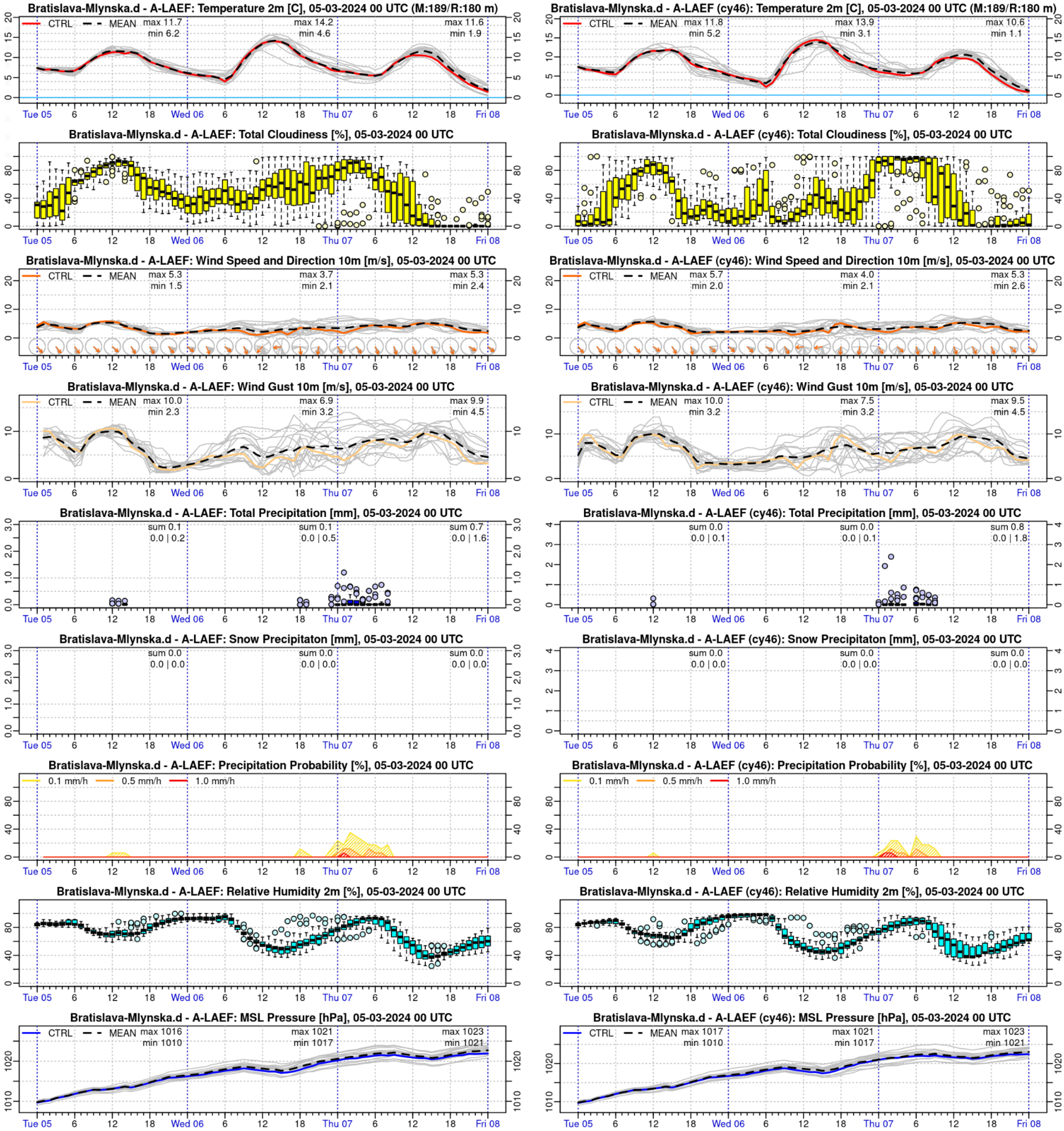

***Fig.10:** Epsgrams for location Bratislava (Mlynská dolina) for the operational A-LAEF system at cy40t1 (left) and for the new A-LAEF system at cy46t1 involving upgraded ALARO physics (right).*

Tab.2: *Differences between daily extremes of the ensemble mean forecast (resp. of the 10/90-percentiles in case of precipitation) of the operational A-LAEF system at cy40t1 and new A-LAEF system at cy46t1 (for the point forecast shown in figure 10). Colours represent the sign of departure (red for negative, blue for positive, green for neutral).*

new - oper	DAY1		DAY2		DAY3	
	min	max	min	max	min	max
T2m	-1.0	0.1	-1.5	-0.3	-0.8	-1.0
FF	0.5	0.4	0.0	0.3	0.2	0.0
FG	0.9	0.0	0.0	0.6	0.0	-0.4
PREC	$0.0^{(10p)}$	$-0.1^{(90p)}$	$0.0^{(10p)}$	$-0.4^{(90p)}$	$0.0^{(10p)}$	$0.2^{(90p)}$
MSLP	0	1	0	0	0	0

::IV New CLIM files

New climatological files for the A-LAEF domain were prepared with the updated physiographic fields (see figure 11), including their low spectral truncation version for the upper-air blending (used in the assimilation procedure). There are basically three main changes against the formerly used climatological files. Newer database ECOCLIMAP-II was employed, which is a twofold database of land cover maps of ecosystems and surface parameters at true 1 km resolution, based on more recent satellite data than its predecessor ECOCLIMAP-I. The second change is in the surface roughness representation, where its thermal component does not include subgrid orography anymore (Mašek and Brožková, 2020), which is obvious from the comparison of given fields (see figure 11, top). Last but not least enhancement is related to the update of fields via PGD (preparation of physiography data used in SURFEX). Updated fields are orographic roughness (from GMTED2010 7.5''), vegetation roughness (from ECOCLIMAP-II) and subgrid orographic characteristics for GWD parameterization (standard deviation, anisotropy and major axis orientation, also from GMTED2010 7.5''). Everything else remains from the old e923 database.

All these modifications should contribute to the improvement of the representativeness of surface fields in the A-LAEF forecasts. It will undergo testing during the final upgrade of the entire ensemble system, which is not yet ready.

Reminder - Due to the absence of subgrid-scale orography in the thermal roughness length field of the new climatological files (configured with LZ0THER=.F. in e923), the following adjustments will be necessary in all respective model namelists for surface assimilation, blending, and integration, following the completion of the aforementioned implementation.

```
&NAMPHY  → LZ0HSREL=.TRUE. (previously FALSE)
&NAMPHY1 → ALRCN2=10. (previously 0.0025)
```

One of the clearly visible benefits of updated climatological files is the higher spatial resolution and better smoothing over the steep orography for surface roughness length, in contrast with the “chessboard” issue seen there before (see figure 12).

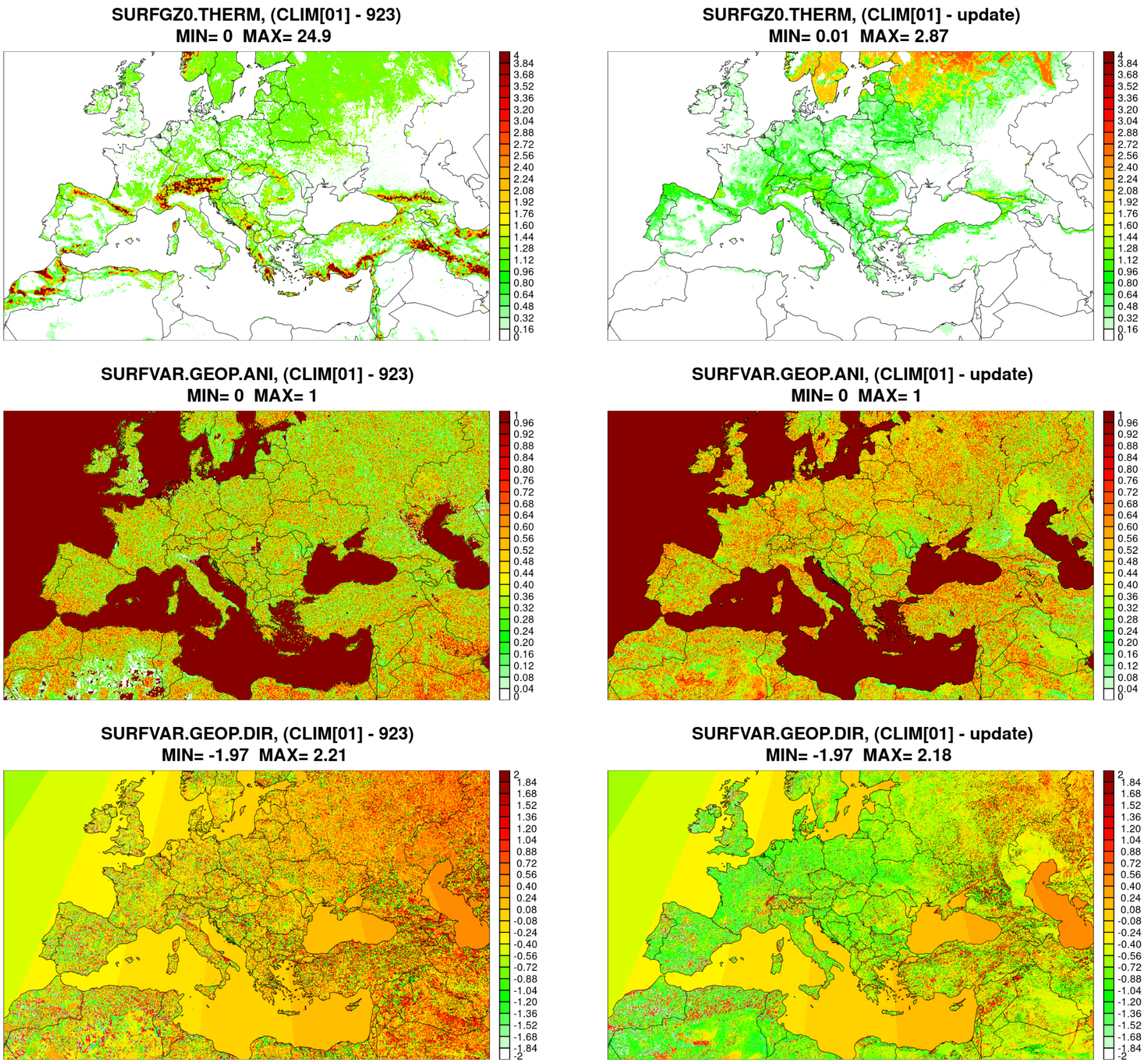

Fig.11: *Thermal roughness length, anisotropy of topography and topography main direction in the old climatological files (left) and in the new updated files (right).*

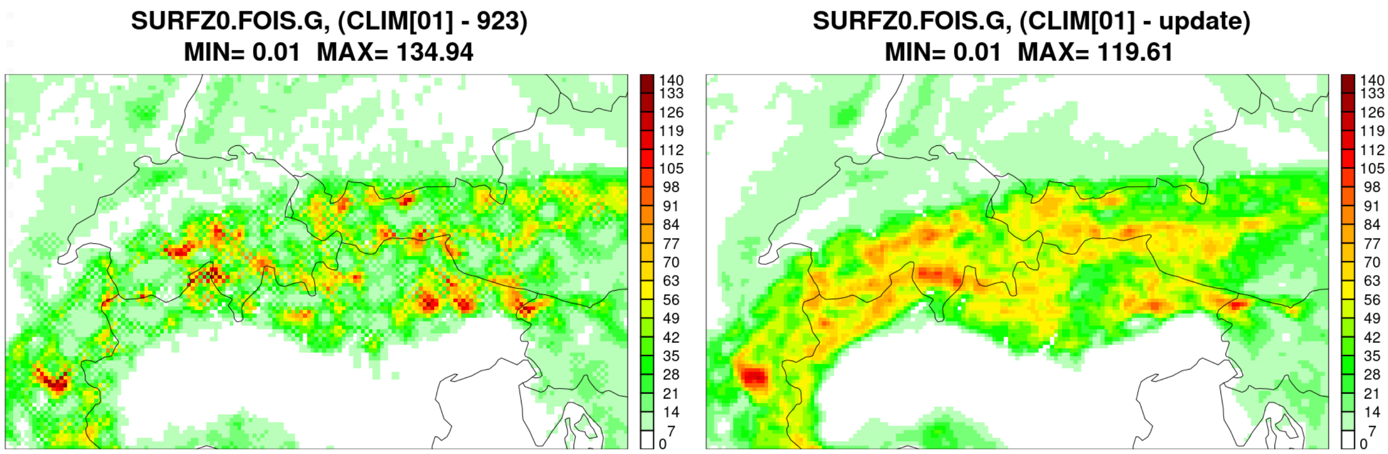

Fig.12: *Mechanical roughness length in the old climatological files (left) and in the new updated files (right). Zoom over the Alps.*

::V Test case

New code used in the A-LAEF system already includes prognostic graupel, diagnostics of 16 precipitation types (see figure 14), flashes, and even more. These are all highly anticipated parameters by the forecasters and should bring useful information about the approaching severe weather. However, it is not always an easy task to process a large amount of new information into a form that would make the work of forecasters easier when making decisions. Therefore, new probabilistic maps for precipitation types (aggregating 4 main products of precipitation) were prepared (see figure 15, right). It was successfully tested during a freezing rain event, which happened at the end of January in south-western part of Slovakia (and Moravia region of the Czech Republic).

Freezing rain event on January 23, 2024 - Bratislava

Synoptic situation: A cold front associated with a large depression over the northern half of Europe passed through our area towards the east. Behind it, moist air streamed into our region from the west to the northwest.

The Emergency Medical Service recorded an extreme increase in injuries and traffic accidents in connection with icy conditions. The worst situation was in the Bratislava region, where alone 22 ambulances were sent to accidents and 4 ambulances to traffic accidents in which the weather played a role. Since Tuesday morning (January 23), the central revenue of the Bratislava University Hospital treated over 50 patients with injuries after slipping on icy sidewalks and roads. Fractures of the lower and upper limbs, head and spine injuries were not an exception. Situation on morning roads was critical as well. Except for several accidents in the city, three trucks collided on the D2 highway in the direction to Bratislava, causing a traffic jam.

In the following figures we show total precipitation forecasted for the first hour after midnight on January 23 for 16 perturbed ensemble members (figure 13) and corresponding most severe precipitation type out of 16 classified species (figure 14). Finally, the new probabilistic maps for 4 aggregated products of precipitation are shown in figure 15 (right), which was in very good correlation with the observed weather situation.

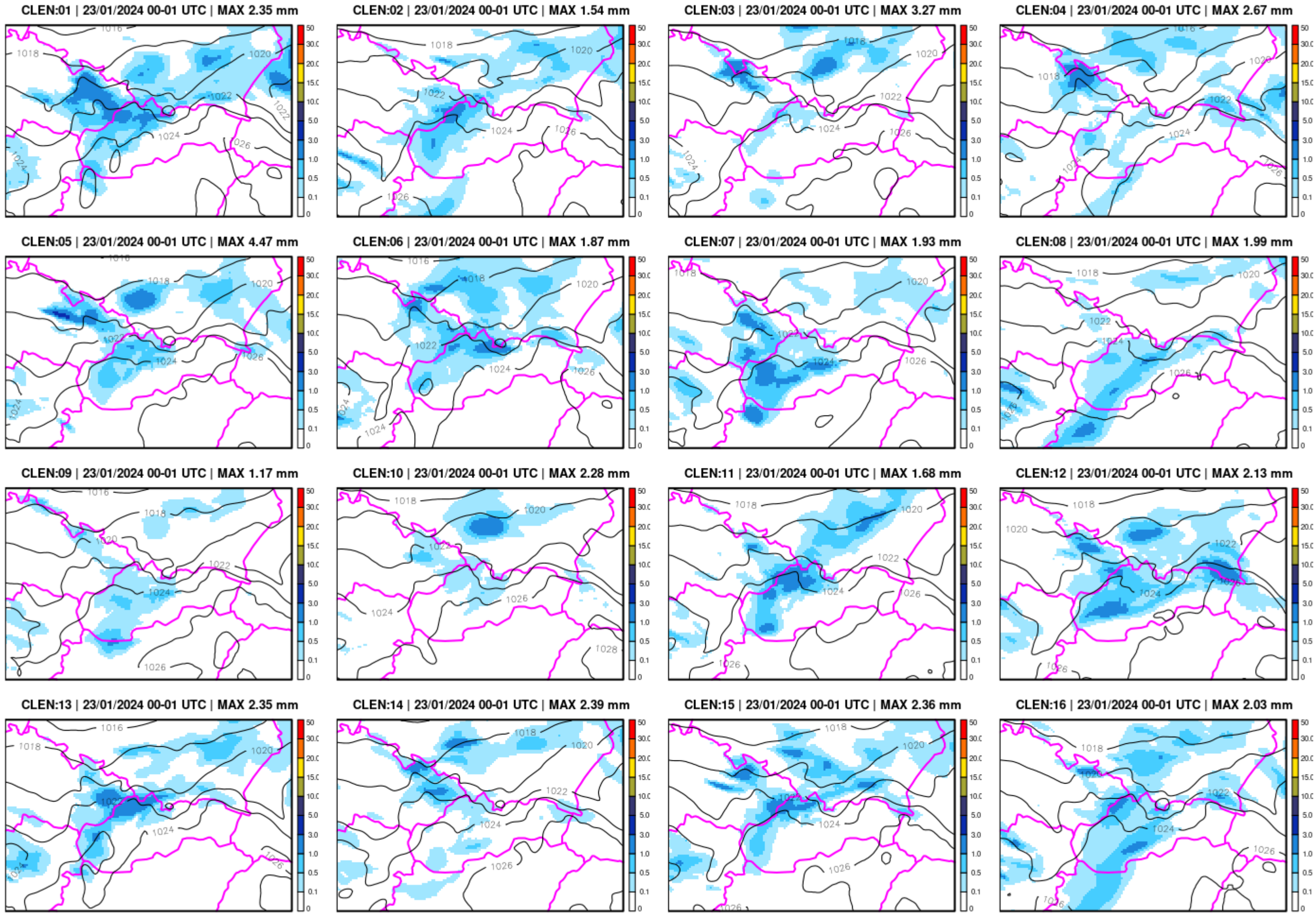

Fig.13: *Total precipitation amount forecasted from midnight to 01 UTC on January 23, 2024 (stratiform+convective rain/snow and graupel) for all 16 perturbed A-LAEF members.*

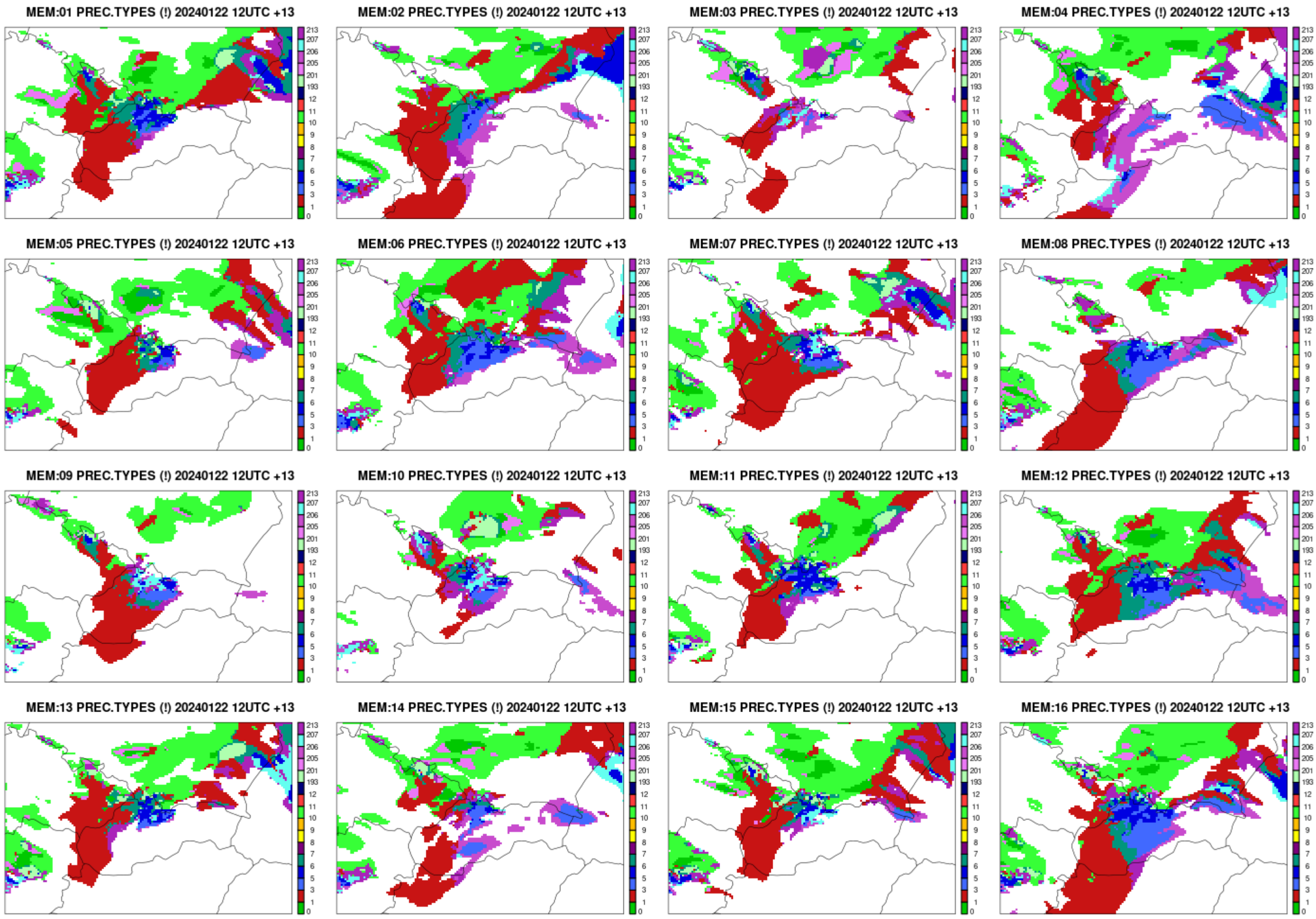

Fig.14: *The most severe precipitation type that occurred from midnight to 01 UTC on January 23, 2024 (16 classified species) for all 16 perturbed A-LAEF members. Freezing rain being displayed in red.*

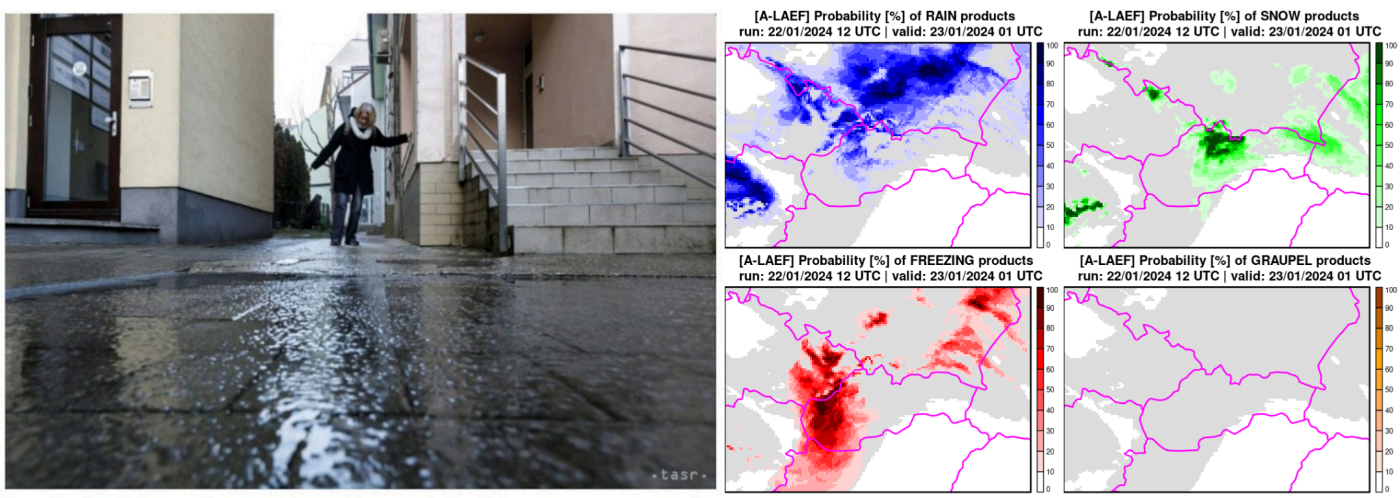

Fig.15: *Frozen rain (photo by TASR) on the sidewalk in Bratislava on January 23, 2024 during the glaze (left). New product depicting probabilities of precipitation types for rain (blue), snow (green), freezing (red) and graupel (yellow) products, with the total area of precipitation in grey (right).*

::Conclusions

Four different physics clusters for the A-LAEF system based on the latest ALARO-1 development at model cycle cy46t1 were set up and tested. It must be noted that a substantial part of this code is generally not available in the cy46t1 export version (nor in the later bugfixes). It includes some add-ons back-phased from newer cycles cy48t3 and cy49t1. New physics clusters were also successfully combined with the stochastic perturbation of the physics tendencies for ISBA surface prognostic fields. This code was locally phased to the cy46t1 as well. Such configuration is capable of producing qualitatively comparable results to those of the operational version (for tested cases). Moreover, it provides new interesting diagnostic fields and should also offer better physics. Apart from the case studies, we expect to carry out a more complex comparison of statistical scores for the new system vs the old one, for a reasonably long verification period (however, this might be difficult due to the computational costs and limited SBUs for research). After the finalisation of the upgrade of all A-LAEF components (e.g. ESDA, post-processing), the new system should become operational in Q3/2024.

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::Appendix

home pack location on Atos (code version without EL1)

```
/perm/sk2/pack/cy46t1.OMPIIFC2104.full
```

content of the pack

```
drwxr-xr-x 2 sk2 sk      10 Jan 24 10:03 bin
-rw-r--r-- 1 sk2 sk  143360 Jan 10 16:01 cy46t1_a-laef_01.tar
-rw-r--r-- 1 sk2 sk 6082560 Jan 10 15:55 cy46t1_czop3_jama.tar
-rw-r--r-- 1 sk2 sk  133120 Jan 10 16:01 cy46t1_sppten_mbell.tar
drwxr-xr-- 2 sk2 sk       4 Jan 10 12:28 hub
-rwxr-xr-x 1 sk2 sk   16826 Jan 10 18:13 ics_masterodb_etc
```

```
drwxr-xr-- 2 sk2 sk      86 Jan 12 10:33 lib
-rw-r--r-- 1 sk2 sk    5998 Jan 12 10:26 mod.list
-rw-r--r-- 1 sk2 sk     161 Jan 11 08:25 README
-rw-r--r-- 1 sk2 sk  447918 Jan 23 10:43 slurm-30649287.out
-rw-r--r-- 1 sk2 sk  448008 Jan 24 10:03 slurm-31007158.out
-rw-r--r-- 1 sk2 sk  562029 Jan 10 18:26 slurm-36178025.out
-rw-r--r-- 1 sk2 sk  504426 Jan 12 10:35 slurm-36717281.out
drwxr-xr-x 5 sk2 sk      14 Jan 24 09:55 src
drwxr-xr-- 2 sk2 sk       4 Jan 10 12:28 sys
```

home pack location on Atos (final version with EL1 modset)

/perm/sk2/pack/cy46t1.OMPIIFC2104.full.EL1

content of the pack

```
drwxr-x--- 2 sk2 sk      10 Feb 28 15:25 bin
-rw-r----- 1 sk2 sk 1269898 Feb 28 13:45 cy46t1_a-laef_full.tar.gz
-rw-r----- 1 sk2 sk  164158 Feb 22 17:16 cy46t1_EL1_jama.tar.gz
drwxr-x--- 2 sk2 sk       4 Feb 28 13:35 hub
-rwxr-xr-x 1 sk2 sk   17098 Feb 28 13:43 ics_masterodb_etc
drwxr-x--- 2 sk2 sk      86 Feb 28 15:23 lib
-rw-r----- 1 sk2 sk     596 Feb 28 14:04 README
-rw-r----- 1 sk2 sk 2035167 Feb 28 15:25 slurm-33360562.out
drwxr-x--- 5 sk2 sk      14 Feb 28 14:35 src
drwxr-x--- 2 sk2 sk       4 Feb 28 13:35 sys
```

/bin

```
-rwxr-x--- 1 sk2 sk 766006656 Feb 28 15:24 BATOR
-rwxr-x--- 1 sk2 sk   3541712 Feb 28 15:24 BLEND
-rwxr-x--- 1 sk2 sk   3493736 Feb 28 15:24 BLENDSUR
-rwxr-x--- 1 sk2 sk    414472 Feb 28 15:24 ioassign
-rwxr-x--- 1 sk2 sk 675755240 Feb 28 15:24 MASTERODB
-rwxr-x--- 1 sk2 sk 162394000 Feb 28 15:25 odbtools.x
-rwxr-x--- 1 sk2 sk   3960208 Feb 28 15:25 PINUTS
-rwxr-x--- 1 sk2 sk   2462784 Feb 28 15:25 PROGRID
```