# NWP related activities in 2024-2025 @SHMU

**5th ACCORD All Staff Workshop, 31.3.-4.4.2025, Zalakaros, Hungary**

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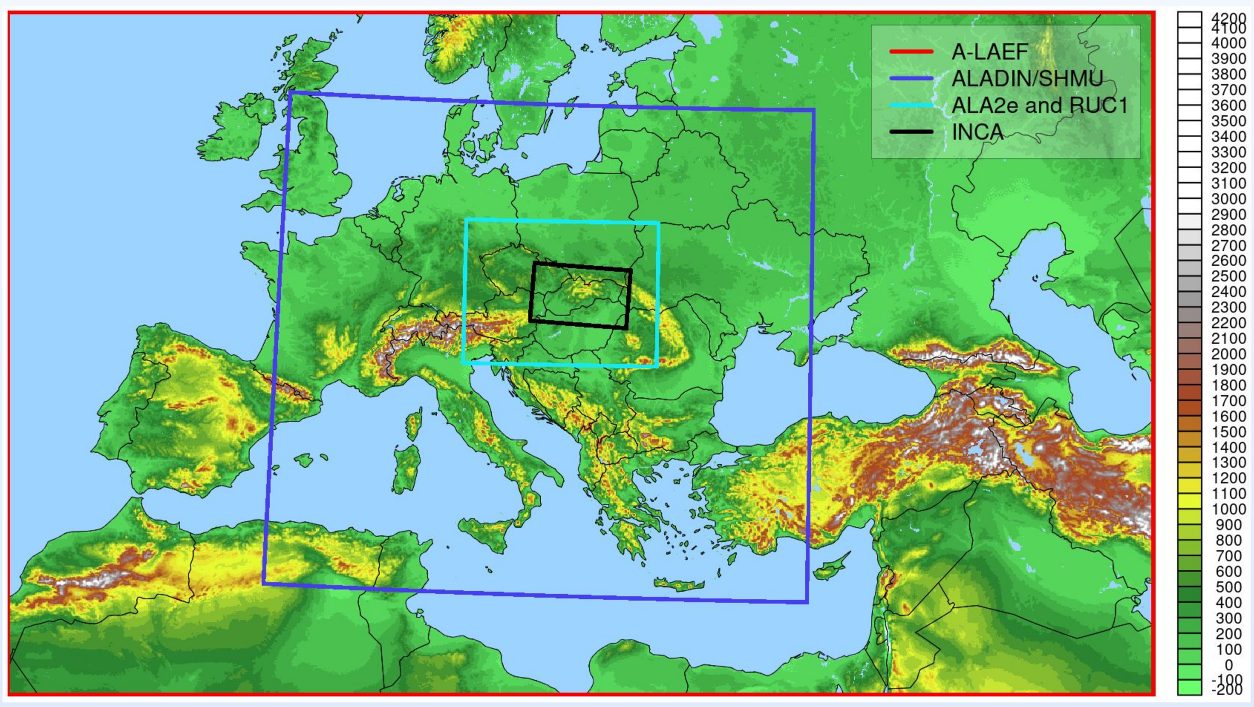
ACCORD – A Consortium for COnvection-scale modelling Research and Development

LACE nwp central europe

## ALADIN (ALARO) systems at SHMU

| CSC | A-LAEF | ALADIN/SHMU | ALA2e | RUC1/ALA1 |
|---|---|---|---|---|
| *status* | operational (common RC LACE) | operational | | test mode |
| *code version* | CY40T1bf07+ | CY46T1bf07 | CY48T3 | CY46T1bf07 |
| *physics* | ALARO-1vB (multi-physics + surface SPPT) | ALARO-1vB | | |
| *dx* | 4.8 km | 4.5 km | 2.0 km | 1.0 km |
| *points* | 1250 x 750 | 625 x 576 | 512 x 384 | 1024 x 768 |
| *vertical levels* | 60 | 63 | 87 | 87 |
| *time step* | 180 s | 180 s | 90 s | 30 s |
| *forecast ranges + frequency* | 72/-/72/- hourly | 78/72/72/60 hourly | 72/-/72/- hourly | hourly, up to +12h or 24h (ALA1) |
| *coupling model* | ECMWF ENS (c903@cy48t2), 6h (time-lagged) | ARPEGE (long- & short cut off), 3h | ECMWF, 3h (time-lagged) | ARPEGE (time-lagged), 1h, SCC |
| *surface data assimilation* | ensemble surface data assimilation (ESDA) by CANARI | CANARI | A-LAEF CNTRL init downscaling | CANARI |
| *upper-air data assimilation* | spectral blending by DFI | Blending by DFI + 3D-Var | | 3D-Var |
| *initialization* | none | none | DFI | DFI |
| *HPC* | Atos Sequana XH2000 AMD (ECMWF) | NEC HPC – 240 nodes, 6230 Intel Xeon Gold Scalable Processors (Cascade Lake), Omni-Path, Linux | | |
| *nodes* | 85 | 40 | 40 | 40 |




### Highlights of the research and development

**Single precision:** 2 weeks of cycling in RUC1, case studies.

**DA:** Ongoing implementation of ZTD GNSS data assimilation with VARBC.

**RUC:** CANARI deep soil wetness tests with 1 h cycling frequency.

**EPS:** A-LAEF e-suite (CY46T1) with upgraded ALARO multi-physics, CLIM files, inline GRIB2 production, dedicated eccodes tables, new prognostic and diagnostic parameters. Operational forecasts of SPEI based on the A-LAEF ensemble in collaboration with climatology department. Case studies.

**ALA2e:** CY48T3 operational from May 2024, graupels added to parameterization of accreted wet snow and ice.

**Climatological modeling:** Downscaling and validation of ERA 5 reanalyses.

**SURFEX:** Analysis of numerical schemes for surface heat balance equation.

**HARP:** Implementation of new methods for quality checks at stations.

**DE_330_MF (DEODE) phase 2 project:** 250 m and 500 m resolution hectometric runs, SRTM orography tests. ALARO-EPS experiments (6+1 members) with new multi-physics and surface SPPT at 1000 m and 750 m spatial resolution.

### Operational highlights

Upgrade of ALA2E to CY48T3

### Near future plans

RUC development, VHR, climate modeling, convection-permitting EPS, single precision, CY49T2 tests

## A-LAEF development

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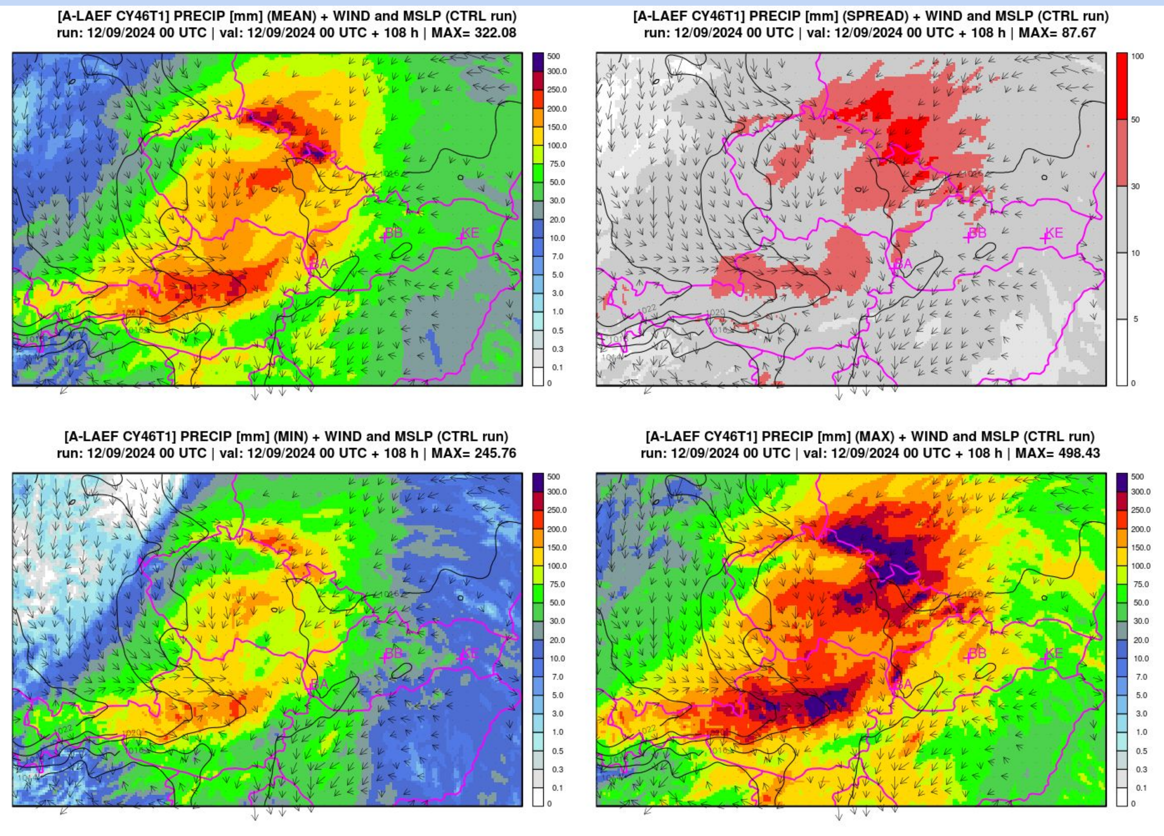
**Upgrade of the system:**

The common operational regional ensemble system of RC LACE is being upgraded to CY46T1, involving all its components like ensemble of surface data assimilation, model uncertainty simulation and postprocessing. Apart from various technical changes, the most significant improvement in terms of enhancing the quality of the model's uncertainty simulation is the implementation of the new ALARO multi-physics. That is based in particular on different parameterizations of evaporation and related microphysics, mixing lengths, and various tunings in connection with the effort to reduce the cold temperature bias.

**Real-time testing of the new A-LAEF system with a +108 h extended forecast:**

Between Sep 13 and 16, 2024, a low-pressure system named Boris brought record-breaking rainfall and extreme winds to central Europe, resulting in severe flooding, blocked roads by fallen trees and damaged power lines. The most affected areas included eastern Austria, regions along the Czech-Polish border, and western part of Slovakia. The predicted total precipitation amounts by A-LAEF ensemble systems (see the maps of ENS mean, spread, min and max below) closely match the observed extreme values, despite such high rates being rarely forecasted by NWP models. The localization of precipitation extremes in the A-LAEF forecast aligns well with the most affected regions. The flooding caused extensive damage, and tragically, loss of lives was also reported.




## EPS at high resolution

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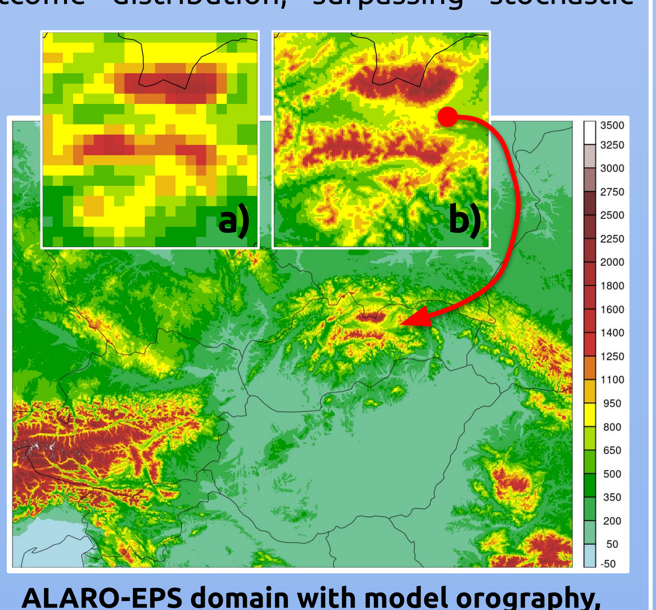
**ALARO-EPS:** We have introduced a multi-physics uncertainty simulation based on the ALARO multi-scale physics parameterization schemes, designed to operate effectively and seamlessly across various spatial scales. This approach is expected to improve uncertainty representation at sub-kilometric resolutions, especially for extreme weather. Different parameterizations respond differently to various weather regimes. Our experience with multi-physics in a 5 km regional ensemble showed a positive impact on outcome distribution, surpassing stochastic perturbations alone.

**Configuration:**

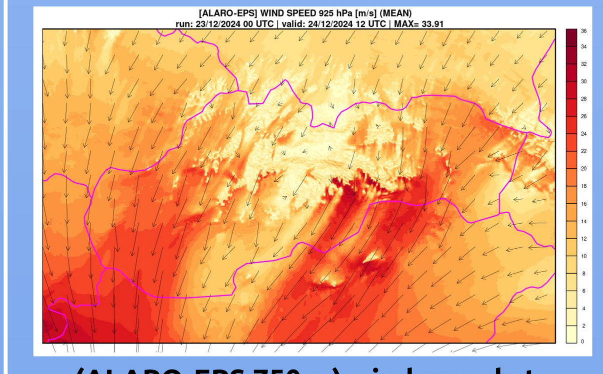
- dx = 750 m, 87 levels
- 1280 x 1024 grid points
- CLIMs: ECOCLIMAP v2.6
- ENS: 6 +1 members
- model uncertainty:
  - ALARO-1 multi-physics
  - surface stochastic physics
- ICs: dynamical adaptation of ECMWF ENS
- LBCs: coupled to ECMWF ENS (MARS DB)
- ecFlow suite based on A-LAEF scripting system



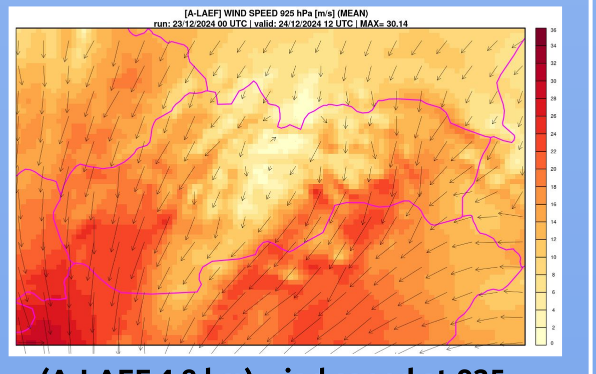

**ALARO-EPS domain with model orography, featuring a zoom on the Tatras: a) A-LAEF@4.8km, b) ALARO-EPS@750m**

**Case studies:**

On **December 24, 2024,** under stable stratification, a downslope wind developed due to wave breaking behind the mountain barrier. Simultaneously, a gap wind formed on a much larger scale. The combination of these two effects can be seen in ALARO-EPS forecast (left) and A-LAEF forecast (right) on the maps below. Although the regional EPS captured this phenomenon quite well, it was detected much more accurately in terms of localization and intensity by the ALARO-EPS with a 750 m spatial resolution.

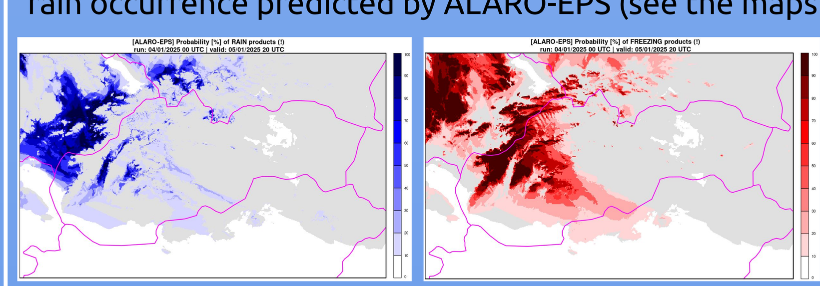


**(ALARO-EPS 750 m) wind speed at 925 hPa (ENS MEAN)**

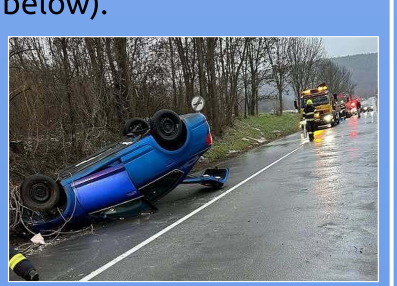


**(A-LAEF 4.8 km) wind speed at 925 hPa (ENS MEAN)**

Morning snowfall on **January 5, 2025,** transitioned to rain by the afternoon, while surface temperatures remained below zero, resulting in freezing rain across western Slovakia. Ice-covered sidewalks and roads became a major hazard in several cities (see a photo from Nitra). These regions match the area of freezing rain occurrence predicted by ALARO-EPS (see the maps below).



**Probability of rain (left) and freezing rain (right)**



**Source: Police SR, Nitra**

## KGE score implementation in HARP

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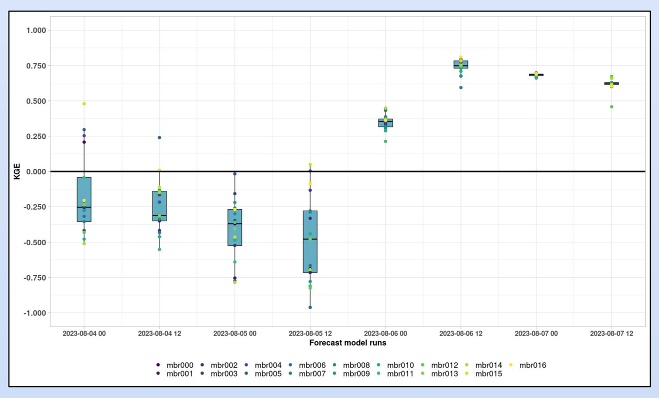
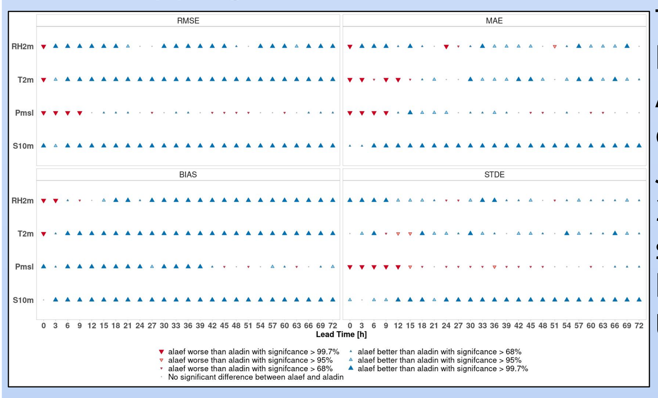


The figure on left presents the KGE score evaluation for an HBV hydrological model forecast based on ensemble A-LAEF model inputs. This case corresponds to a flooding situation at Plešivec-Štítnik. The boxplots display the KGE scores for different forecast model runs, with individual ensemble members shown as colored points.

A perfect model achieves KGE=1. Values close to 1 indicate good agreement between observed and modeled data. Negative values indicate poor model performance.

### Bootstrapping verification



The left graph displays a scorecard bootstrap(Harp) comparison of the A-LAEF and ALADIN/SHMU models over the verification period from July 1, 2024 at 00:00 to December 31, 2024 at 12:00. It illustrates the statistical significance of differences between the models for various lead times.

The blue triangles indicate that A-LAEF performs better than Aladin. The red triangles signify that A-LAEF performs worse than Aladin. Gray dots represent cases where no significant difference is detected between the two models.

## Radar assimilation - LRADAR_SIGMA3CHECK

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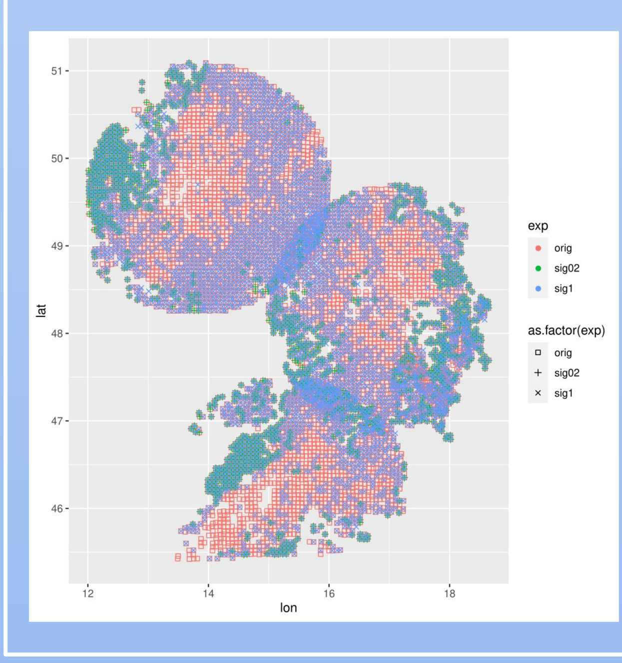
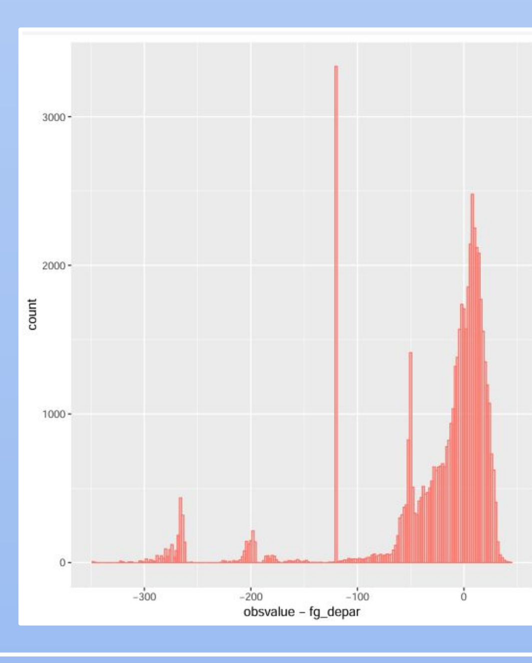
During our RC LACE stay in Prague [November 2024], in cooperation with CHMI colleagues, we focused on the impact of LRADAR_SIGMA3CHECK [&NAMSCC] on radar DA screening. When the model profile ZEXP/ICOMT is further than (3*ZRADARXSIG)**2 from the observation, we do not use that profile (ICOMT is the counter of valid observations in the column). The model also produces reflectivities down to -300 dBZ (right figure), while observations are no less than -40 dBZ. In such cases, not enough observations close to radars pass through Bayesian inversion in inv_refl1dstat.F90 (left figure). Therefore, we do not recommend setting LRADAR_SIGMA3CHECK to true.



## Analysis of numerical schemes for surface heat balance equation

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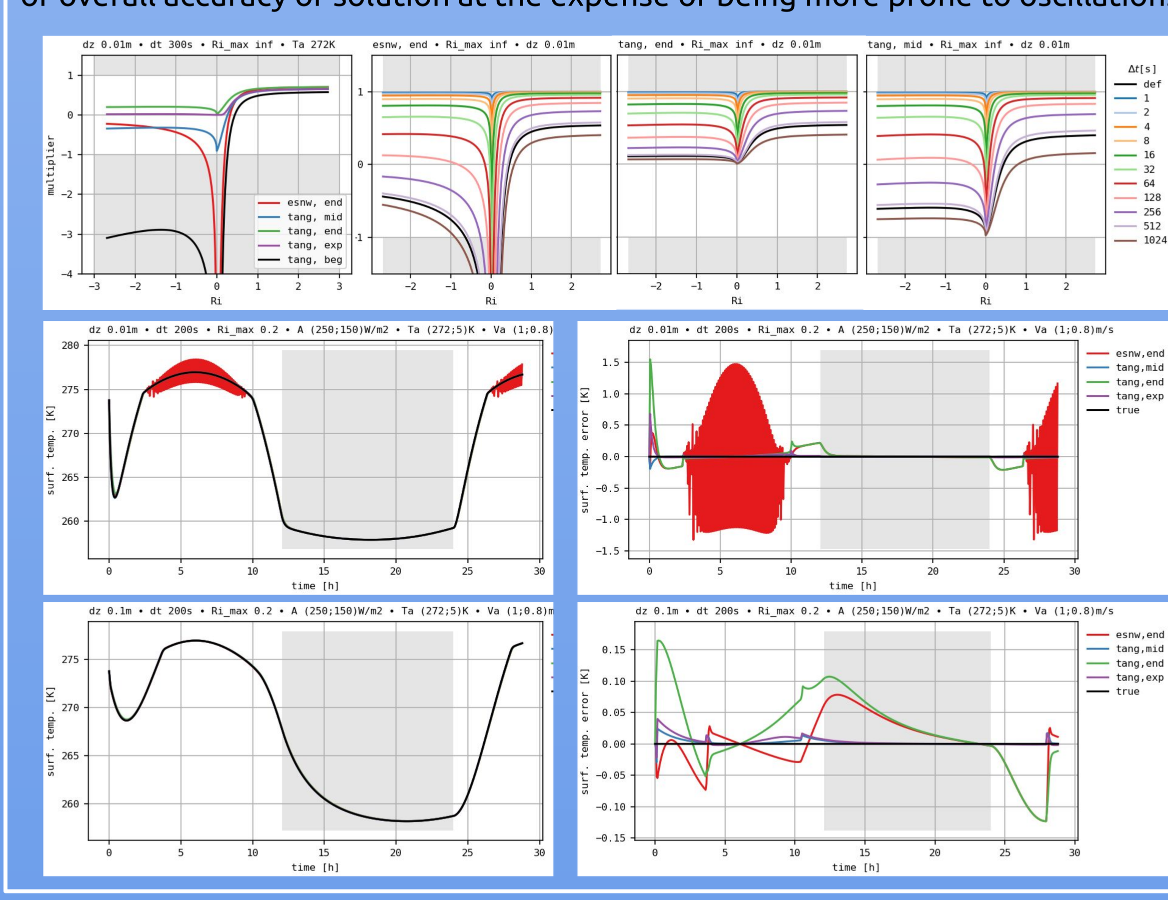
Accurate representation of temperature gradient in heat diffusion solver of snowpack model may result in too thin top numerical layer which is prone to numerical oscillations and instability. This is true also for overall thin snowpacks. Numerical oscillations were detected in offline SURFEX with Explicit snow or Crocus models. We derived alternative variants of numerical scheme for snow surface heat balance equation denoted (tang,end), (tang,mid) and (tang,exp). Original scheme of explicit snow model is denoted (esnw,end). All schemes are implicit. Linear stability analysis (top figures) suggests that for Ri close to 0 (neutrally stable atmospheric surface layer) original scheme is numerically unstable for time steps exceeding approximately 30s for 1cm thick snow surface layer. Alternative schemes are stable even for very long time steps at arbitrary Ri. To prevent numerical oscillations in original and (tang,mid) schemes (middle figures) time step must be set below approximately 10s and 30s, respectively. In contrast, (tang,end) and (tang,exp) schemes provide numerically non-oscillatory solution for arbitrary time step size. Excellent stability properties of (tang,end) and (tang,exp) schemes are however penalized with somewhat larger error of solution (bottom figures). On the other hand (tang, mid) scheme is best in terms of overall accuracy of solution at the expense of being more prone to oscillations.




## RUC1 - experiments with smoothing of the deep soil water reservoir

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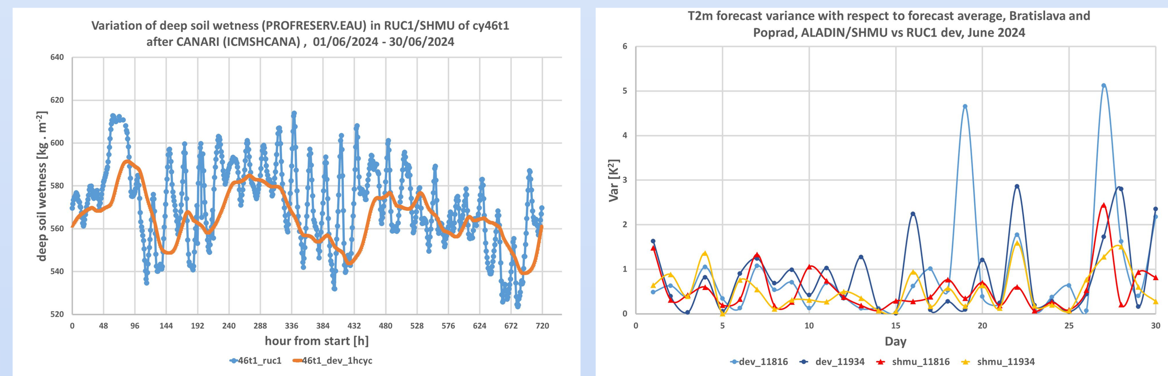
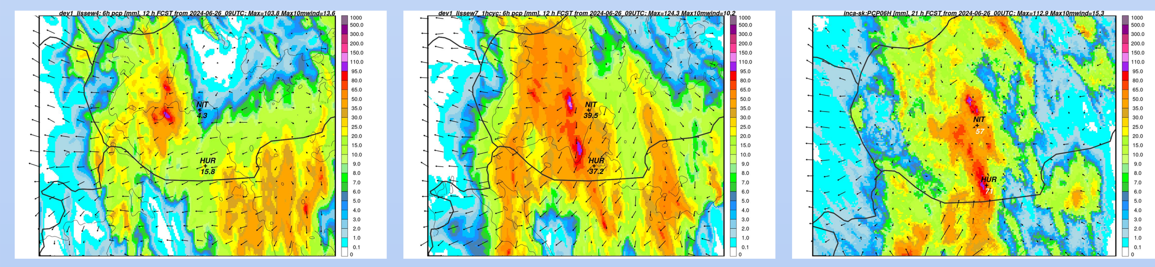



**RUC1: reference, regular run**
**Dev: RUC1, smoothing and 1h cycling**

**SHMU: ALADIN/SHMU operational run**
**Dev: RUC1 with smoothing & 1h cycling**

Similar to other NWP systems, the RUC1 also exhibits oscillations of the deep soil wetness (PROFRESERV.EAU), which may result in oscillations in forecasts of 2m temperature as well. Previously, the smoothing (with setting LISSEW=.T. in CANARI) was tested with 3h cycling. Current tests were provided with 1h cycling frequency (and NLISSEWMAX=23). While the deep soil wetness was smoothed during the experiment (left figure), it can be shown that the variance in 2m temperature (calculated from +0, +6, +12, +18 and +24h forecasts, valid for 12 UTC ) is occasionally still high and even bigger than for ALADIN/SHMU - probably due to high uncertainty in situations with deep convection (right figure).



**6h precipitation: "dev" forecasts with deep soil wetness smoothing in case of 3h cycling (left), 1h cycling (middle) and the verifying analysis (right).**

In cases with severe convection, the dev experiment with smoothing and 1h cycling performed better than for 3h cycling and for original RUC (not shown).

## DE_330_MF project: case studies at high (up to 250 m) resolution

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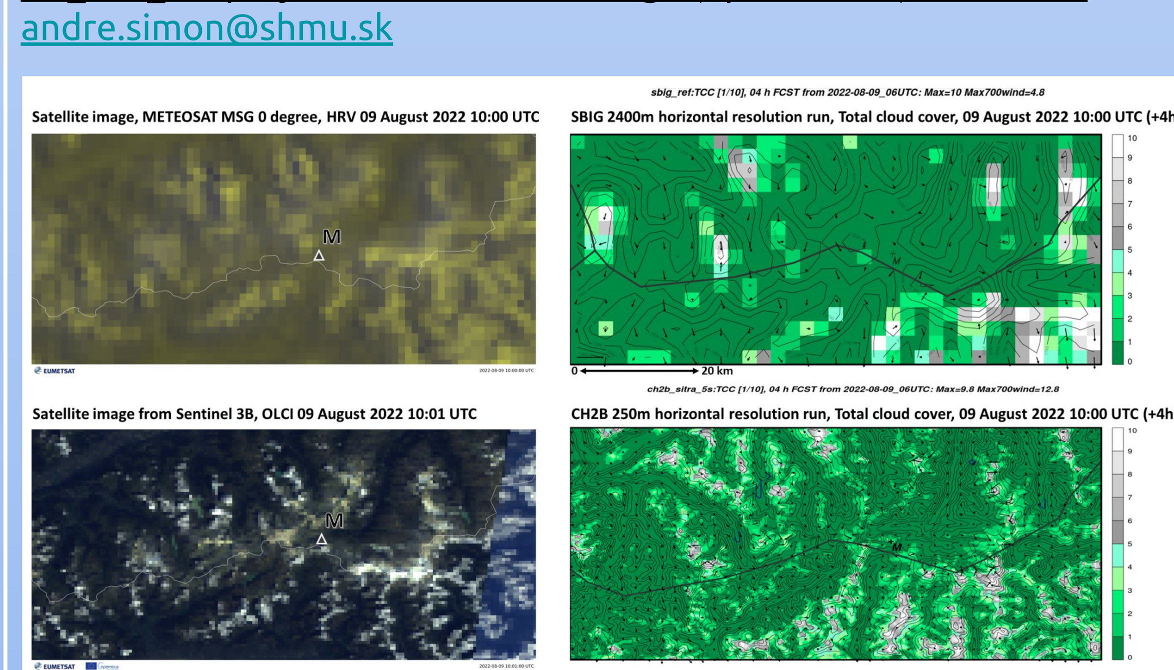


**Left: Satellite images from METEOSAT HRV channel (top, max. resolution 1km) and Sentinel 3B (bottom, max. resolution 300m) over the Alps, area of Matterhorn. Right: ALARO simulations of Total cloud cover on experimental SBIG (top, dx=dy=2.4 km) and CH2B domain (bottom, dx=dy=250 m) for the same region.**

One possibility of comparing model forecasts with observations at hectometric scale is to use very high resolution satellite imagery (from MTG or from low earth orbit satellites as Sentinel 3B). The example above shows the cloudiness at the border of Italy and Switzerland, in the area of Matterhorn (denoted with letter "M" in the figures). In situations with weak (subcritical) flow around the mountains, convective clouds start to form above the ridges at noon. With detailed model orography (as in the CH2B domain) one can forecast similar cloudiness distribution as seen on the Sentinel 3B image.

"This work is funded by the EU under agreement DE_330_MF between ECMWF and Météo-France. The on-demand capability proposed by the Météo-France led international partnership is a key component of the weather-induced extremes digital twin, which ECMWF will deliver in the first phase of Destination Earth, launched by the EC."

## Evaluation of the single precision use in CY46T1

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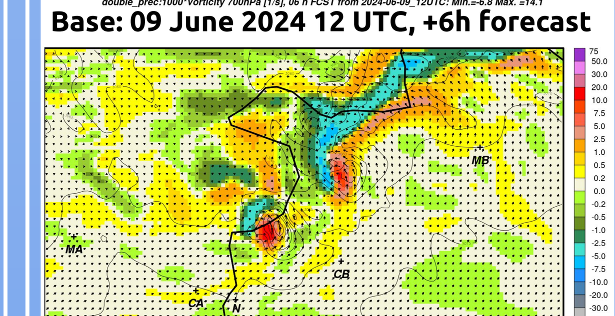
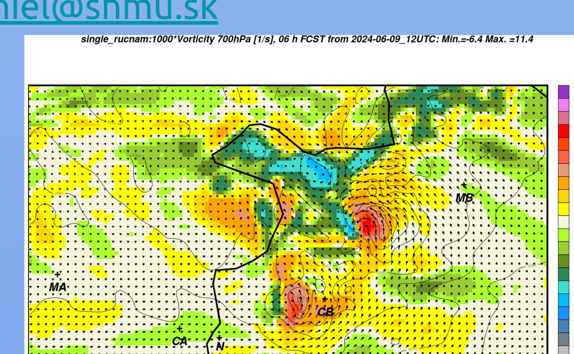
**Base: 09 June 2024 12 UTC, +6h forecast**



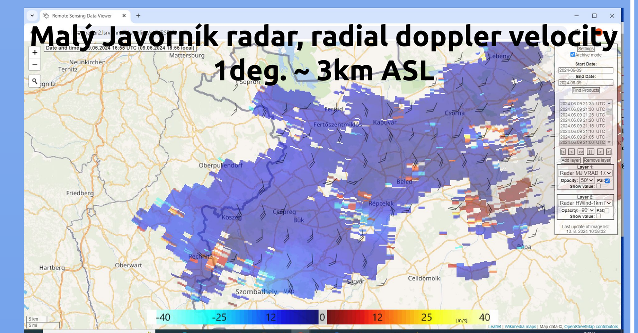
**RUC1, double precision, 700 hPa vorticity**



**RUC1, single precision, 700 hPa vorticity**

We experimentally run the ALARO configuration (RUC1 domain) with single precision on several cases with severe convection, e.g. in the case of supercell thunderstorms on 09 June 2024 at the Austrian-Hungarian border (see the figures above and to the right).

**Malý Javorník radar, radial doppler velocity 1deg. ~ 3km ASL**



The single precision runs were able to forecast the examined severe events in the selected cases, mostly indicating similar position and intensity. Two week scores (not shown) were mostly nearly neutral with respect to RUC but worse for specific humidity. Integration wall-times decreased by 35-40 percent.