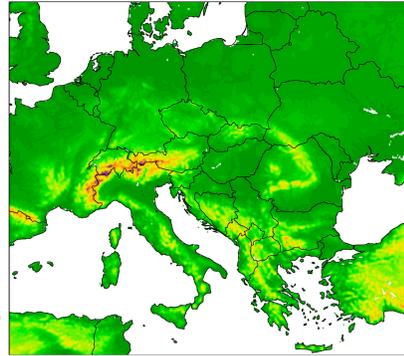


Operational configurations

ALADIN/HU

- Model version: cy40t1 (ALARO-v1b physics)
- 8 km horizontal resolution, 49 vertical levels
- Local data assimilation:
 - 3D-Var in upper air, optimal interpolation at surface
 - 6-hour assimilation cycle
 - Short cut-off analysis for the production runs
 - Downscaled ensemble background error covariances
- Digital filter initialization
- 4 runs a day: at 00/06/12/18 UTC up to 60/48/60/36 h
- 3 hourly lateral boundary conditions from ECMWF-"HRES"
- Hourly outputs

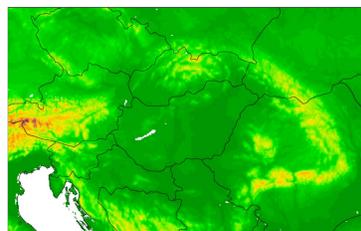


ALADIN/HU model domain

AROME/HU

- Model version: cy43t2_bf11
- 2.5 km horizontal resolution, 60 vertical levels
- Local data assimilation:
 - 3D-Var in upper air, SEKF at surface
 - 3-hour assimilation cycle
 - Lake temperature initialized from measurements at Lake Balaton
 - Hydrometeors & snow cycled in assimilation
- Initialization: space-consistent coupling (no DFI)
- 8 runs a day: 00/06/12/18 UTC up to 48h; 03/09/15/21 UTC up to 36h;
- LBCs from ECMWF-"HRES" with 1h coupling frequency
- SBL scheme over nature & sea to calculate the screen level variables
- Hourly outputs for forecasters, special outputs in every 15 minutes for commercial users & hail prevention system

Assimilated observations (via OPLACE)	
ALADIN/HU	AROME/HU
• SYNOP (u, v, T, RH, z)	• SYNOP (u, v, T, RH, z)
• SYNOP-SHIP (u, v, T, RH, z)	• TEMP (u, v, T, q)
• TEMP (u, v, T, q)	• AMDAR (u, v, T, q)
• AMDAR (u, v, T)	• Slovenian & Czech Mode-S MRAR (u, v, T)
• ATOVS (AMSU, MHS radiances)	• GNSS ZTD (IWV)
• MSG/GEOWIND (AMV)	• AMV, HRWIND (u, v)
• MSG/SEVIRI (radiances)	



AROME/HU and AROME-EPS domain

AROME-EPS

- 11 ensemble members using AROME
- Local perturbations: 3 hourly ensemble data assimilation
- 2 forecast runs a day, at 0 and 12 UTC up to 48 hours
- Hourly LBCs from 18/6 UTC ECMWF-ENS
- Resolution, physics etc. as in AROME/HU

Computer system

- HPE Apollo 6000 server
- 22 nodes x 2 CPU x 20 cores, 2.2 GHz Intel XeonE5-2698 processors
- 128 GB RAM/node
- IFS LBCs from ECMWF via Internet, backup ARPEGE LBCs from Météo-France

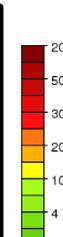
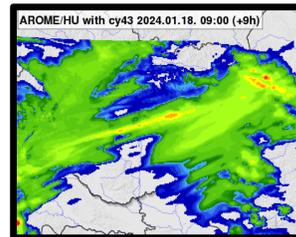
Testing AROME cy46t1_bf07

We started to implement AROME cy46t1 on the HPC of the Hungarian Meteorological Service dedicated to research. This is an HPE Apollo 2000 Gen10 server with IntelXeon Gold 5220R processors at 2,4 GHz. The AROME code was compiled with Intel compiler version 18.0 using gmpack 6.7.3. The main pack is cy46t1_bf07 and some local modifications are also implemented: initializing lake temperatures with observation at Balaton, adding snow properties to the SURFEX initial file and the upper air FA file, introducing the upper limit of 1.0 for saturated water vapour mixing ratio over liquid water and ice.

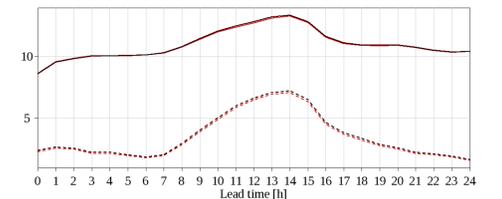
After installation of the model, some tests were carried out to check the forecast and assimilation configurations. Afterwards 2 longer periods were computed with the new model cycle: (1) from 6 January to 11 February 2024 and (2) for June 2024. In these experiments the same model set-up was applied as in the operational AROME/HU.

The beginning of 2024 was characterized by strong cyclonic activity. The synoptic scale systems often brought rain, freezing rain, snow and even sleet. High wind gust values were also observed in the period. Nevertheless, the impact of **cy46t1** was neutral wrt. the operational **AROME/HU**, even for precipitation case studies.

3-hour precipitation amount [mm] between 6 and 9 UTC on 18 January 2024



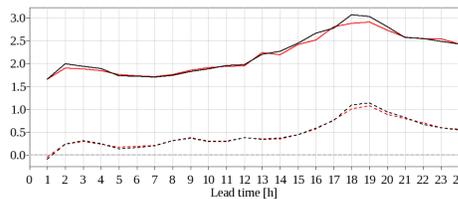
RMSE (-) and bias (-) of 2-meter relative humidity [%] 6 January – 11 February 2024, 0 UTC runs



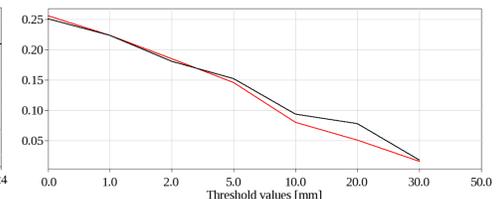
In June several frontal systems passed over Hungary, with heavy rains, thunderstorms, hails. Using cy46, a slight improvement is seen in near-surface wind and temperature. The verification scores show a small degradation for high precipitation amounts, but the case studies don't confirm this.

The new model cycle will be evaluated in real time by forecasters in winter. Its operational switch is scheduled for February in 2025. The single precision option and the Fast Fourier Transform in the West algorithm will be also tested.

RMSE (-) and bias (-) of 10-meter wind gust [m/s] June 2024, 0 UTC runs



ETS of 30-hour forecasts for 24h precipitation amount June 2024, 0 UTC runs



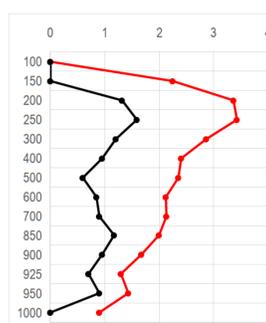
Testing assimilation of Mode-S EHS data in AROME

We have started to extend the current assimilation of aircraft data in AROME/HU with Mode-S EHS to compensate the anticipated reduction of AMDAR data as well as the recent dramatic drop of national Mode-S MRAR data. Mode-S EHS data from EMADDC are available in OPLACE, both the regular and fast BUFR files with 15- and 5-minute window, respectively.

Experiments were carried out using the fast data in the AROME/HU model at 2.5 km resolution. A pre-thinning Python program from *Siebrén de Haan* was used for the initial experiment with the following box-thinning settings: box heights of 300,300,600,1000 m; box width of 40 km. The minimization process with this setup finds the minimum after approximately 100 iteration steps. We noticed that instrumental (AMDAR, MRAR) data are only available below the level of 200 hPa, whereas **Mode-S EHS** data are available at higher levels. This is likely because private jets can reach much greater heights.

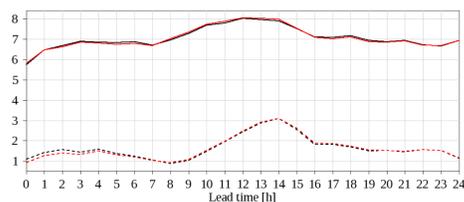
In a second experiment set, the **SIGMAO_COEF** representing the observation error was raised from the default value of 0.9 to **2.8** in case of aircraft data. The experiments were carried out (1) from 27 November to 10 December 2023 and (2) for June 2024.

Logarithm of number of assimilated aircraft data AMDAR+MRAR vs. AMDAR+MRAR+EHS 1 December 2023 0 UTC

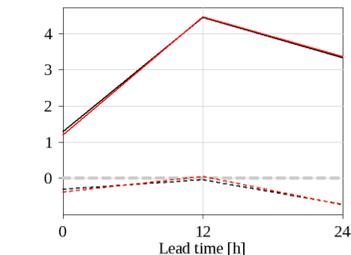


The observation monitor showed normal OMG and OMA statistics for the experiments. The verification results mainly indicated neutral impacts wrt. **AROME/HU**. Some improvements were detected in 2-meter relative humidity and mean sea level pressure in winter, in precipitation in summer and occasionally in high-level winds.

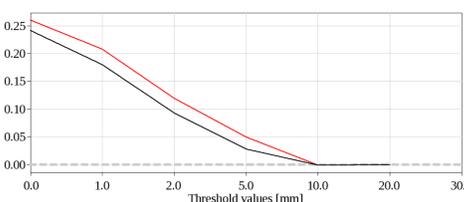
RMSE (-) and bias (-) of 2-meter relative humidity [%] 27 November – 10 December 2023, 0 UTC runs



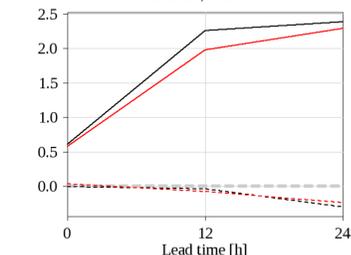
RMSE (-) and bias (-) of wind speed at 200 hPa [m/s] 27 November – 10 December 2023, 0 UTC runs



ETS of 12-hour forecasts for 3h precipitation amount June 2024, 0 UTC runs



RMSE (-) and bias (-) of wind speed at 500 hPa [m/s] June 2024, 0 UTC runs



After a careful revision of the thinning procedure, we plan to implement the Mode-S EHS data into our hourly AROME-RUC e-suite, too. We expect higher impact in RUC considering that with its very short cut-off we lose many AMDAR data.

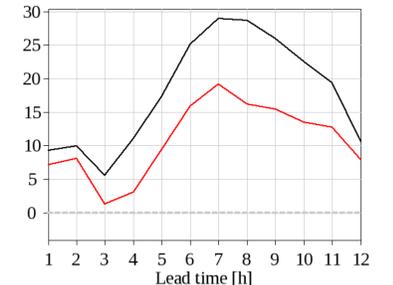
E-suite at 1.3kmL90 resolution and with hourly assimilation

In autumn 2023 we launched the e-suite of AROME Rapid Update Cycle with hourly assimilation using 3D-Var and SEKF at 1.3 km horizontal resolution and 90 levels. 30 minutes after the nominal initial time we immediately start the assimilation procedure and then the forecast. 12-hour forecasts run at 3, 9, 12, 15 and 18 UTC, while 30- and 24-hour forecasts are prepared at 0 and 6 UTC, respectively. The forecast can be delivered in real time after 1 hour. A long cut-off assimilation cycle is scheduled 2 hours after its nominal initial time.

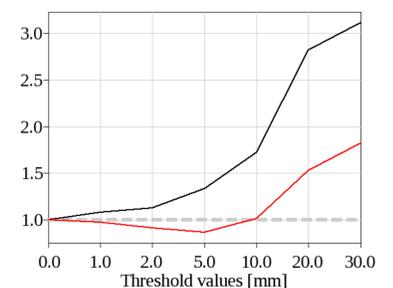
Based on the verification results, **hourly analysis updates together with high resolution** improve the overestimation of incoming surface solar radiation with respect to the 3 hourly cycled **operational AROME/HU**. Added value can be detected also for precipitation: the distribution of afternoon precipitation events is more realistic in the e-suite than in the operational version.

Always a great attention is paid for the weather situation on 20 August due to the open-air events related to the national holiday, especially the fireworks at 19 UTC over the Danube in centre of Budapest. In 2024 a system with heavy rains and thunderstorms approached the place of interest. The 12 UTC **IFS run** expected almost no convective activity for the evening, while the corresponding (and succeeding) AROME/HU and AROME-RUC runs provided reliable forecasts (led to postponing the fireworks with 1 hour).

Radiation bias [W/m²] 16 April – 16 September 2024, 6 UTC runs



Frequency bias of 3h precipitation amount 16 April – 16 September 2024, 14–17 UTC, 9 UTC runs



3-hour precipitation amount [mm] between 18 and 21 UTC on 20 August 2024

