Numerical Weather Prediction at Czech Hydrometerological Institute

39th EWGLAM & 24th SRNWP EUMETNET Meetings, 2 - 5 October 2017, Reading, UK

NWP system

ALADIN/CHMI couples hydrostatic dynamics and the set of ALARO-1 physical parameterizations suited for modeling atmospheric motions from planetary up to the meso-gamma scales:

- domain 529x421 grid points, Δx~4.7km
- linear truncation E269x215
- 87 vertical levels, mean orography
- time step 180 s
- 3h coupling interval
- 00, 06, 12/18 UTC forecast to +72/54h
- hourly analysis system VarCan Pack
- **ALADIN cycle 38t1tr_op6 (ALARO-1vB)**

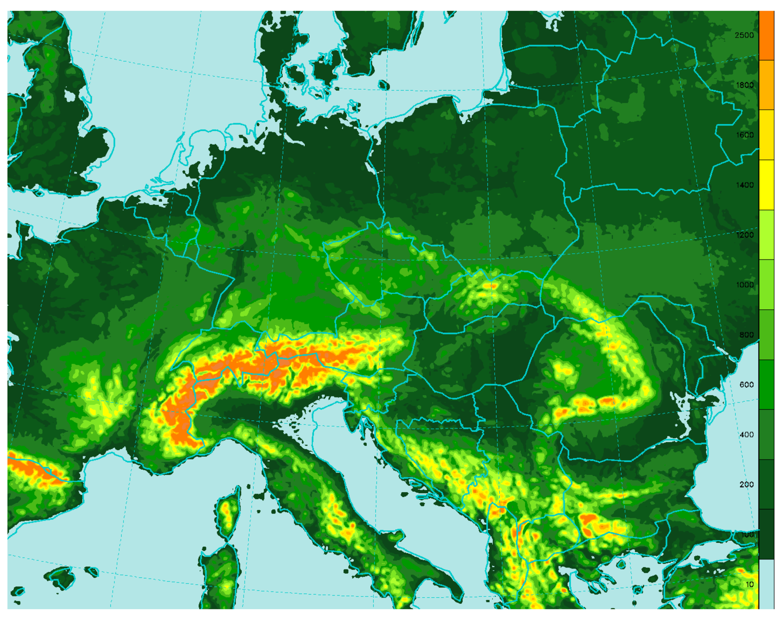

Figure 1: Orography of model domain

Data assimilation includes surface analysis based on an optimal interpolation (OI) and **BlendVar** analysis for upper air fields, which consists of the digital filter spectral blending (Brozkova et al., 2001) followed by 3DVAR analysis based on the incremental formulation originally introduced in the ARPEGE/IFS global assimilation (Courtier et al., 1994, doi: 10.1002/qj.49712051912).

- digital filtering at truncation E87x69; space consistent coupling
- no DFI in long cut-off 6h cycle; incremental DFI in short cut-off production analysis

HPC system

- Two full **NEC SX-9** nodes (1TB RAM and peak performance 1.6 TFLOPS provided by 16 vector CPUs each node)
- GFS with 118TB usable disk space
- operating system is SUPER-UX
- NQSII scheduler
- two Linux **frontend servers** (4 Intel Xeon quad core CPUs, 2.93 GHz clock rate and 31 GB RAM each)

Porting activities to new HPC system

The new HPC solution with peak performance more than 80 times faster than the currently used system is scheduled to be put into operation in early 2018.

- **NEC LX series** HPC cluster
- 320 computing nodes connected through high-speed Mellanox EDR InfiniBand
- each node consists of two **Intel Broadwell** CPU (12 cores, 64GB RAM)
- **7680 computational cores** in total
- operating system is CentosOS 7.2 Linux OS
- more than 1 Petabyte of storage capacity and bandwidth performance of more than 30 GB/s
- SLURM scheduler

Major operational changes (Sept 2016 – Sept 2017)

20 Jun 2017 - implementation of local Mode-S MRAR data assimilation
- optimization of aircraft data assimilation

The high resolution aircraft **Mode-S MRAR** observations available in the airspace of the Czech Republic are implemented.

- observations obtained from air traffic surveillance systems (Mode-S radars) (Strajnar 2012, doi:10.1029/2012JD018315)
- quality of Mode-S MRAR data is similar to AMDAR
- positive impact was found in the nowcasting context and in the first hours of NWP forecast

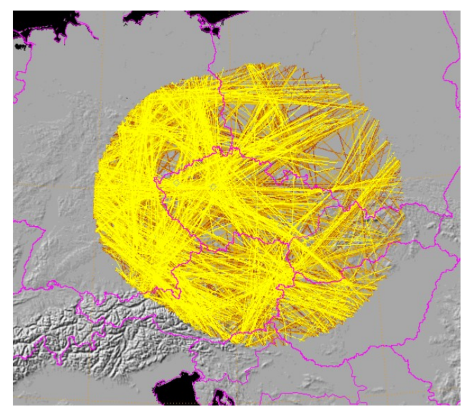

Figure 1: Geographical coverage.

Further overall **optimization of aircraft (MRAR & AMDAR) data assimilation** included:

- reduction of horizontal thinning distance from 50km to 25km
- increase of the vertical thinning to 15hPa
- inflation of observation errors by coefficient 2.8

The optimization brings slight positive impact in the first hours of forecast, see Figure 2:

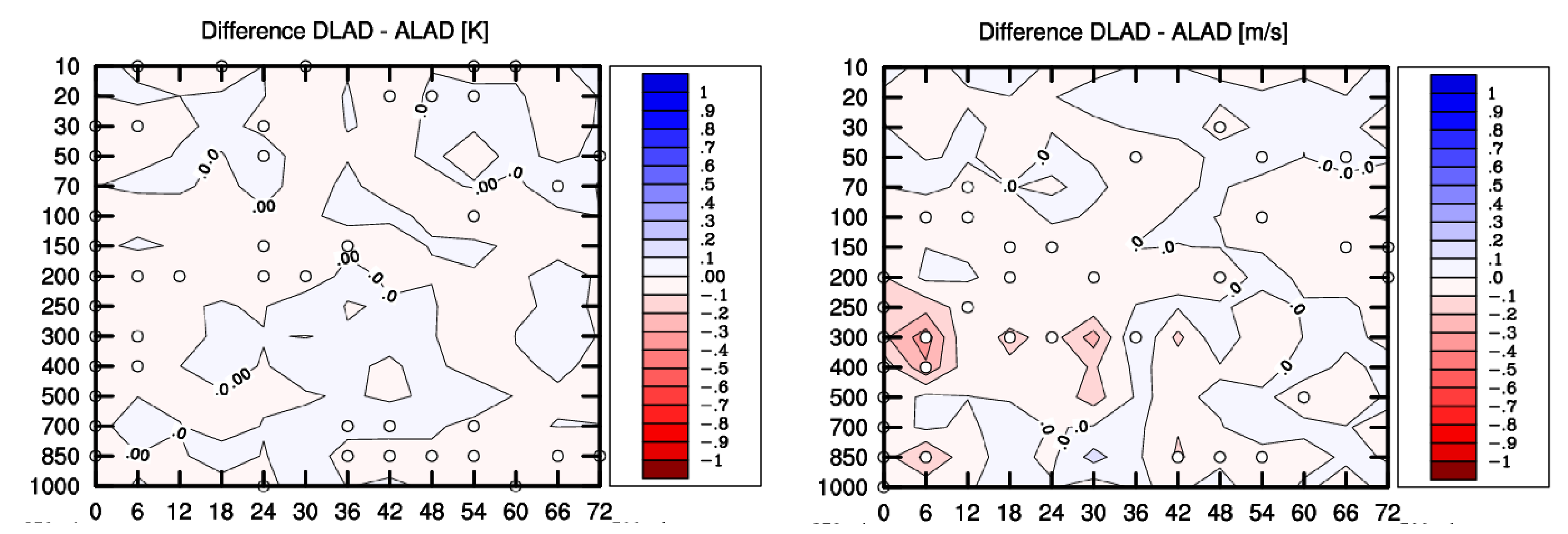

Figure 2: **RMSE differences of temperature** (left) and **wind speed** (right) for period of 11 May – 20 Jun 2017 12UTC. Red areas denote better performance of optimized aircraft data assimilation with respect to operational runs. The white circles point that RMSE difference is better/worse with significance 95% two-side confidence interval.

The optimized aircraft data assimilation improved simulation of the precipitation band over the northwest of the Czech Republic, see Figure 3.

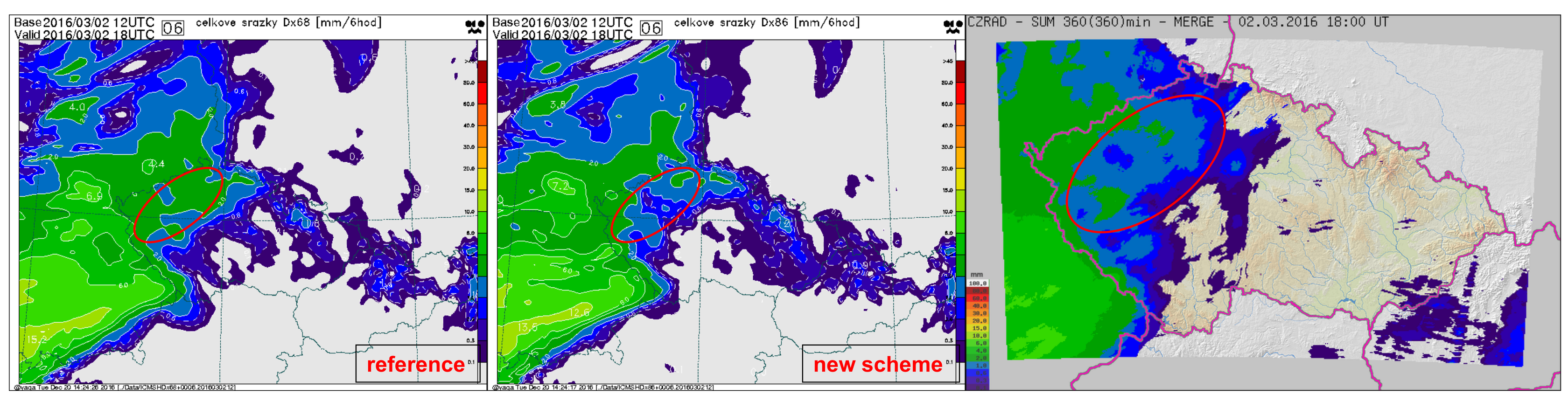

Figure 3: 6h precipitation forecast for 2 March 2017 12UTC for lead time of +6h for reference (left), the new scheme (middle) and observations – radar and rain gauges based quantitative precipitation estimate (right).

Background error covariance for a BlendVar assimilation system

A new background error covariance matrix suitable for the so-called BlendVar scheme is proposed by Bučánek and Brožková, 2017, doi:10.1080/16000870.2017.1355718. BlendVar deals with a problem on how to best preserve large-scale information of the global coupling system in the high-resolution LAM analysis. The scheme is composed from a DF Blending step, treating the inclusion of the global model analysis, and from high resolution 3D-Var. We are enhancing the BlendVar scheme by a new construction of the background error covariance matrix which forces 3D-Var to act mainly at smaller scales. In order to sample background error covariances, we create a LAM BlendVar ensemble where every member is blended with the same global analysis and following 3D-Var is using perturbed observations (the ensemble is called ENSBV further on).

Variance spectra of ENSBV are compared to ensemble-assimilation method (Berre et al., 2006), called ENS. Figure 2 shows that variance of long waves is drastically reduced in ENSBV compared to ENS while the variance spectra for waves shorter than ~30 km are close between ENSBV and ENS.

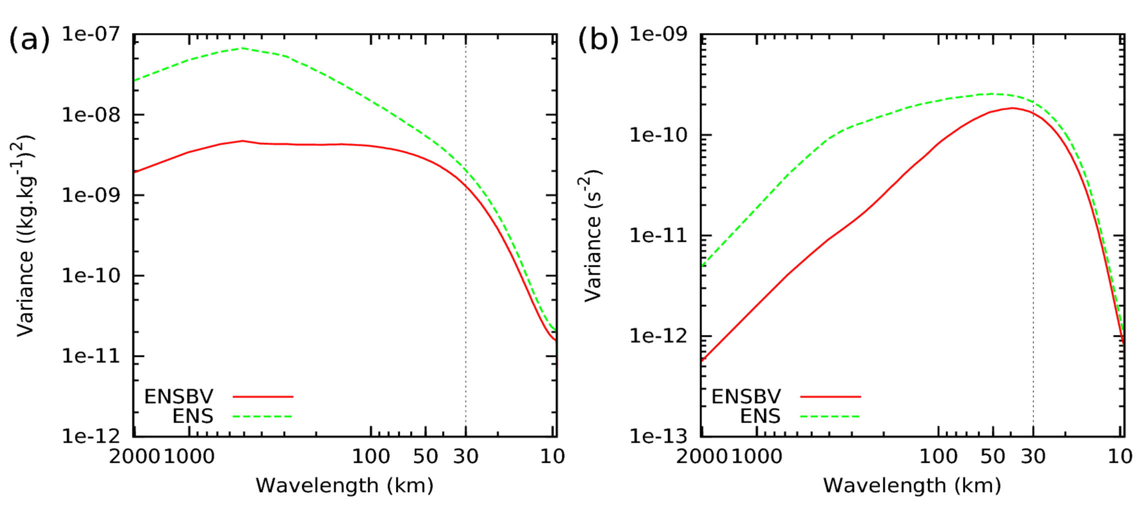

Figure 1: Horizontal variance spectra of background errors at ~850 hPa for (a) specific humidity, (b) vorticity for ENSBV and ENS spectra and the black dotted line indicates wavelength of the DF Blending cut-off truncation.

The ENSBV background errors seems to be more appropriate for the BlendVar scheme than ENS ones. In order to verify this, we prepare four experiments:

- BlendVar_ensbv – BlendVar with ENSBV
- BlendVar_ens – BlendVar with tuned ENS
- Blending - DF Blending scheme only
- 3D-Var_ens – only 3D-Var with tuned ENS

All DF Blending-based experiments perform better with respect to the experiment using only 3D-Var over the 1-month period. This indicates that the driving model analysis gives an important improvement to the initial conditions. Although differences are very small, new set-up is promising.

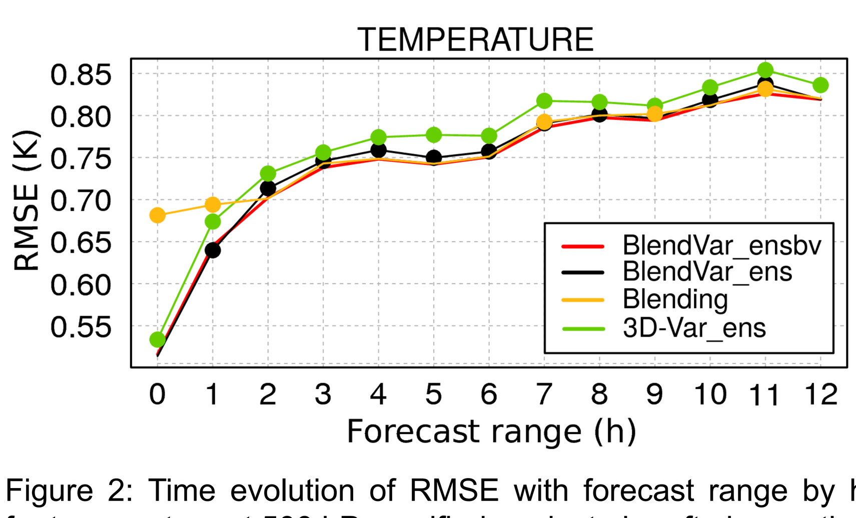

Figure 2: Time evolution of RMSE with forecast range by hour for temperature at 500 hPa verified against aircraft observations.

Further improvements of moist buoyancy term in TOUCANS

The Intensity of turbulent transport is highly influenced by phase changes of water, causing changes of density and energy release/consumption. Recently the so-called mass flux based computation was introduced in ALARO-1, leading to a direct estimation of moist Brunt Vaisala Frequency and of the related moist buoyancy term instead of using a modified moist Richardson number.

In this study we further improve the scheme. Parameterization of weighting function, serving as a kind of interpolator between non-saturated and fully saturated cases, takes into account the moisture variability within a grid box in a more realistic way.

We present here the impact on total water, where turbulent transport becomes stronger and enhances the lift of water from near surface layers higher up. It is well seen on the water vapour budget difference between the reference and the modified version, see Figure 1, computed over Central Europe for the case of 29 Jun 2017.

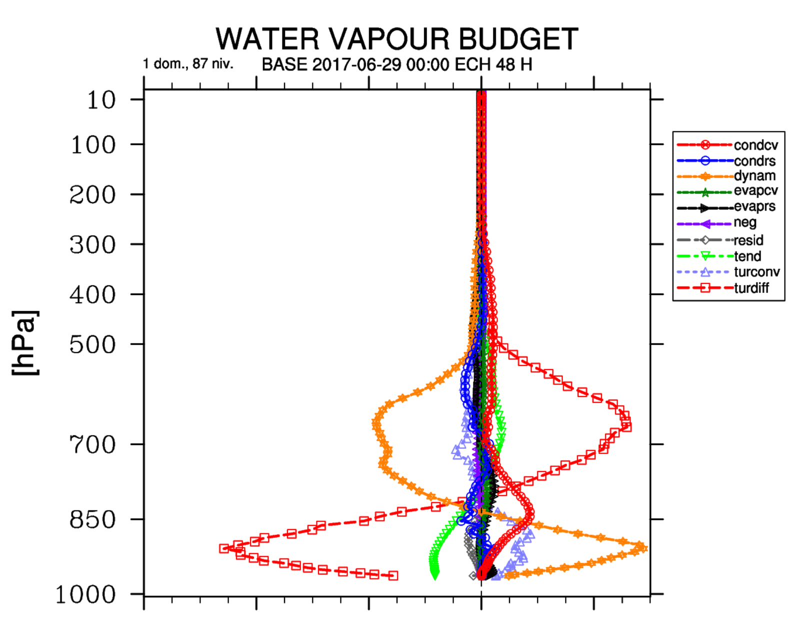

Figure 1: Water vapor budget difference between the reference and modified scheme for 29 Jun 2017.

Redistribution of water improves scores of the model, namely of relative humidity, where both bias and RMSE are better. Here we show scores over 8 summer days with a strong precipitation activity.

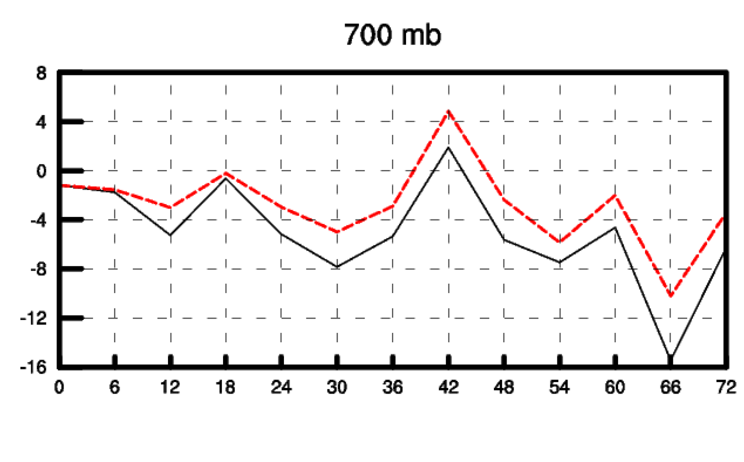

Figure 2: BIAS at 700hPa for **OPER** and **modified scheme** for 8 days from 25 Jun – 2 Jul 2017.with a strong precipitation activity.

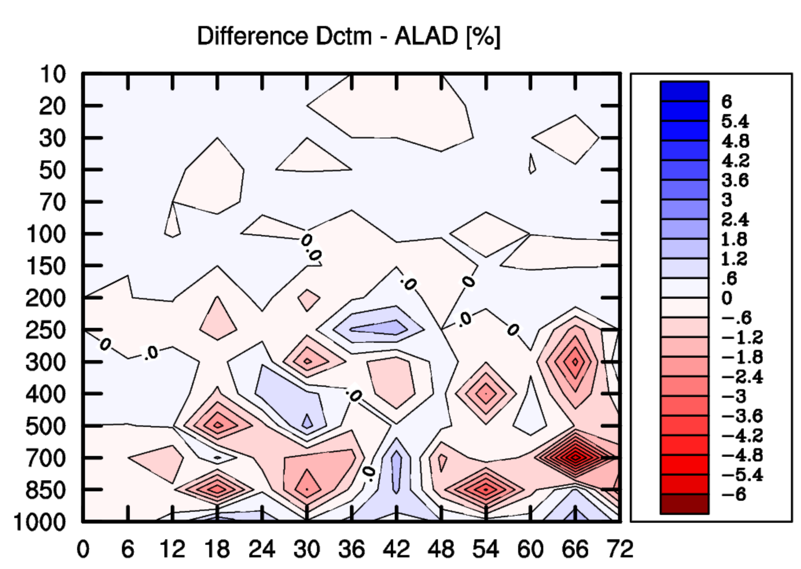

Figure 3: **RMSE differences of relative humidity** for period of 25 Jun – 2 Jul 2017. Red areas denote better performance of the modified scheme.