Operational implementation of BlendVar scheme at CHMI

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1 Introduction

The quality of the analysis is essential in numerical weather prediction. Limited area models (LAM) with its high resolution allow better representation of small scale component of the analysis while keeps difficult to correctly specify large scales. The problem is reduced in the ALADIN model at CHMI by combination of the 3D-Var assimilation method and the Digital Filter (DF) Blending method (Brožková et al. 2006; Derkova & Bellus 2007) in a scheme so called BlendVar.

We were inspired by a variational assimilation in global spectral models that use the multi-incremental approach for faster convergence (Veerse & Thepaut 1998). They are first searching solution for very long waves. Subsequently the spectra is enlarged to incorporate shorter waves and search of solution is repeated. LAMs cannot correctly analyse long waves due to its limited area. Thanks to DF Blending we are able to transfer long wave part of analysis of driving model (ARPEGE) to LAM ALADIN while keeping short wave part of the first-guess. This is an analogy of the first step of the multi-incremental approach. Following 3D-Var with its direct use of observation should analyses mainly scales which cannot be represented in the driving model.

DF Blending was operationally used at CHMI from 2001 to August 2015. The parallel suite of the BlendVar scheme was implemented in the first quarter of 2015 and tested with few minor modifications up to 20th August 2015, when BlendVar was switched to operational use.

DF Blending was not modified during the implementation. Following sections briefly resume setup of new BlendVar scheme and its performance.

Model setup used as reference:

- Cycle 38t1tr_op3 (ALARO-1),
- Resolution – 529x421 grid points, linear truncation E269x215, Δx=~4.7 km, 87 vertical levels, mean orography,
- Time step 180 s, coupling interval 3 h,
- OI surface analysis based on GTS SYNOP (T2m, RH2m),
- 6h assimilation cycle without initialization in the next +6h guess integration,
- DF Blending – filtering at truncation E87x69,
- Incremental digital filter initialization is used in production,
- Production of forecast is done 4 times a day: 00, 06, 12, 18 UTC up to +54 h.

2 BlendVar setup

The BlendVar assimilation system uses a six-hour forward intermittent cycle as is shown in Fig 1. A six-hour forecast (ALADIN+6H.prev) from a previous cycle is used as a first guess. This guess is used in surface data assimilation (Optimal Interpolation) then it is blended with the global ARPEGE analysis (ARPEGE+0H) using DF Blending. The resulting background field is combined with observation in the 3D-Var assimilation scheme. The analysis is used as initial condition for the following 6h forecast that creates first guess of next assimilation cycle. Data assimilation scheme is performed at 00, 06, 12 and 18 UTC.

Only components of the wind, temperature, specific humidity and surface pressure are analysed by 3D-Var. The other atmospheric prognostic fields are taken from the background fields, which helps to maintain balance in the analysis.

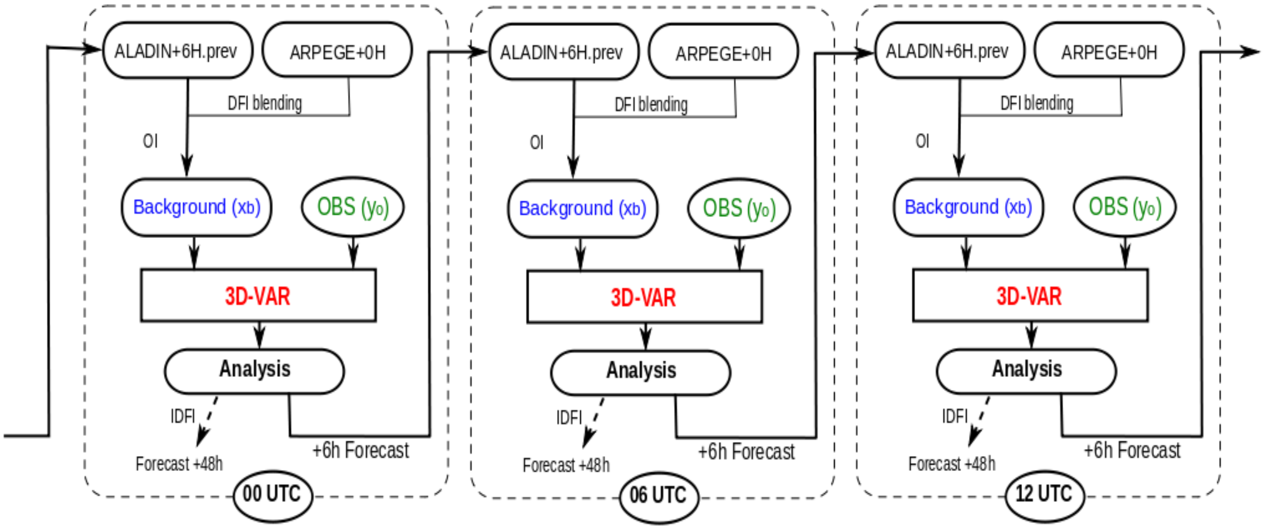

Figure 1: Data assimilation system scheme in model ALADIN/CZ

Specification of background error matrix is essential component of 3D-Var because it filters and propagates observed information (Berre & Desroziers 2010). The background errors were produced by ensemble method (Berre et al. 2006) for three months period of February – May 2011. More details of our selection of background errors could be found in Trojáková (2013).

2.1 Error diagnostics and tuning

Desroziers et al. (2005) proposed a posteriori diagnostics that are supposed to represent the real standard deviations of observation and background errors in the given data assimilation system. The diagnosed values divided by the predefined ones define the ratio $r = \sigma_{diagnosed}/\sigma_{predef}$ to be used for tuning of analysis. The tuning was done in ALADIN 3D-Var by multiplying REDNMC and SIGMAO_COEF namelist parameters by reached ratios r. The diagnostics showed that the background errors are overestimated while observation ones are underestimated. Final tuning corresponds to namelist parameters: REDNMC=1.7 and SIGMAO COEF=0.67, see Trojáková (2013).

2.2 Used observations

We are assimilating observations of:

- air pressure from ground stations (SYNOP),
- temperature, relative humidity, wind speed and direction from aerological sounding (TEMP),
- satellite radiances from Meteosat-10 (channels 2, 3, 4, 5, 6),
- derived satellite product AMV (Atmospheric Motion Vector),
- temperature, wind speed a direction from aircraft measurements (AMDAR).

Conventional observations (e.g. synoptic stations, radiosondes) as well as geostationary satellites measurements are assimilated at analysis time, while aircraft observations are analyzed within 3-hour assimilation window.

2.3 Bias correction - VarBC

Variational Bias correction (VarBC) with 24-hour cycling of bias parameters is used to correct a satellite bias. The bias parameters (included in VarBC files) are initialized for the SEVIRI instrument from model AROME and warmed-up in passive assimilation mode for 1.5 months.

In this passive mode, the background constraint on the bias parameters is modified through the namelist parameter NBG_MSG_HR (in both namel_screen, namel_minim). Taking into an account that the "satellite bias" itself is flow-dependent, we increase the NBG parameter up to 20000 (default 5000) to control the slow adaptation of bias parameters that is important for statistically meaningful estimates. In active assimilation mode is kept the default NBG value.

2.4 IDFI setup and coupling

We have decided to use space consistency coupling in assimilation cycle and production because it improves short range forecast (up to +6 h). Incremental digital filter initialization (IDFI) was re-tuned in BlendVar scheme to allow shorter waves in initial conditions. Namelist parameter TAUS was reduced from 5400s to 1800s and number of time step was reduced accordingly. More detail could be given on request from our internal report (ask Patrik Benacek).

3 Performance

3.1 Case study – Flood 2013

The Czech Republic was affected by several flood event during June 2013. The first event with heavy precipitations falling from June 1 to June 3 was the most severe one with respect to the life lost and damage. Precipitation accumulations exceeded locally 100 mm/24 h especially in the mountain regions. The period had high sensitivity on initial conditions, which was appropriate for the assimilation case study.

BlendVar setup was very similar to above mentioned one, only Meteosat-10 radiances were not used. Quality of forecasts was verified by standard statistics, e.g. RMSE, STDE, BIAS against ground and aerological observations on period of 26. 5. – 10. 6. 2013. Statistics were compared against reference (the operational setup from January 2014, cy36_op8). BlendVar initial conditions were significantly improved against reference that shows only proper setup of the new system. Predictions of relative humidity from 00 UTC had the best scores with positive impact up to 24 h (Fig 3). Impact of assimilation on other upper air fields was rather neutral for forecast longer than 6 h.

We focused on verification of extreme precipitations over Czech republic during 1.–2. June. About 700 stations were selected and their 24 h precipitation accumulations were interpolated to 1 km regular grid. Model outputs were converted to the same grid and objective scores of frequency bias and fraction skill score (FSS, Roberts a Lean 2008) were computed. Scores of frequency bias showed that BlendVar reduced overestimation of low precipitation thresholds and underestimation of high thresholds for prediction. BlendVar improved FSS for all verified thresholds of predictions starting from 00 and 06 UTC on 1. 6. 2013, see Fig 4. Subjective verification of 24 h precipitation accumulations also favors the BlendVar setup.

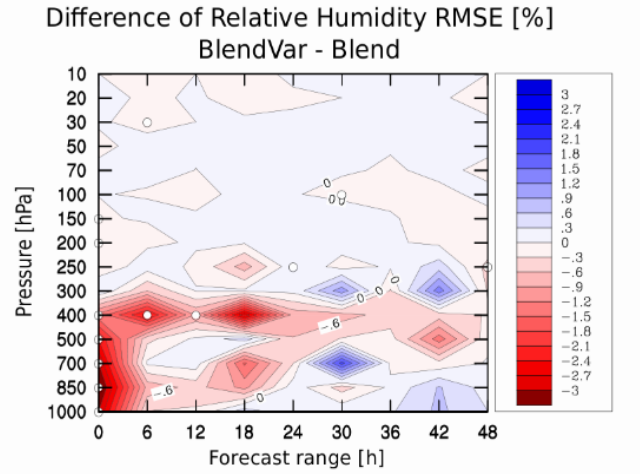

Fig 3: RMSE difference BlendVar - reference of relative humidity for the period 26. 5. – 10. 6. 2015, red areas denote positive impact of BlendVar

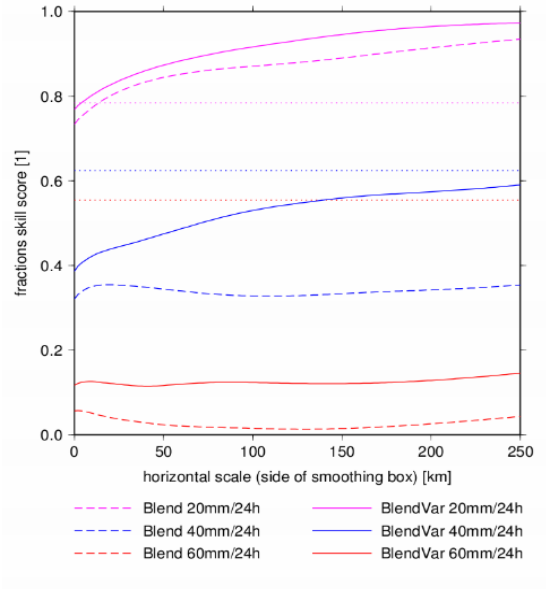

Fig 4: FSS of BlendVar and reference for three thresholds (20, 40, 60 mm/24h). Forecast from 06:00 UTC 1. 6. 2013.

3.2 Performance of parallel suite AKC

BlendVar configuration and modified surface analysis (for more details see Appendix) were tested in a parallel suite AKC over the period 25. 6. – 20. 8. 2015. BlendVar showed significant improvement in fit of analyses to assimilated observations. Impact on forecasts was smaller, but mostly positive (Fig 5). Subjective comparison of precipitations over the Czech Republic favour the BlendVar configuration although the differences against reference were very small during the examined period. Setup of parallel suite AKC became operational on 20. 8. 2015 at 12 UTC.

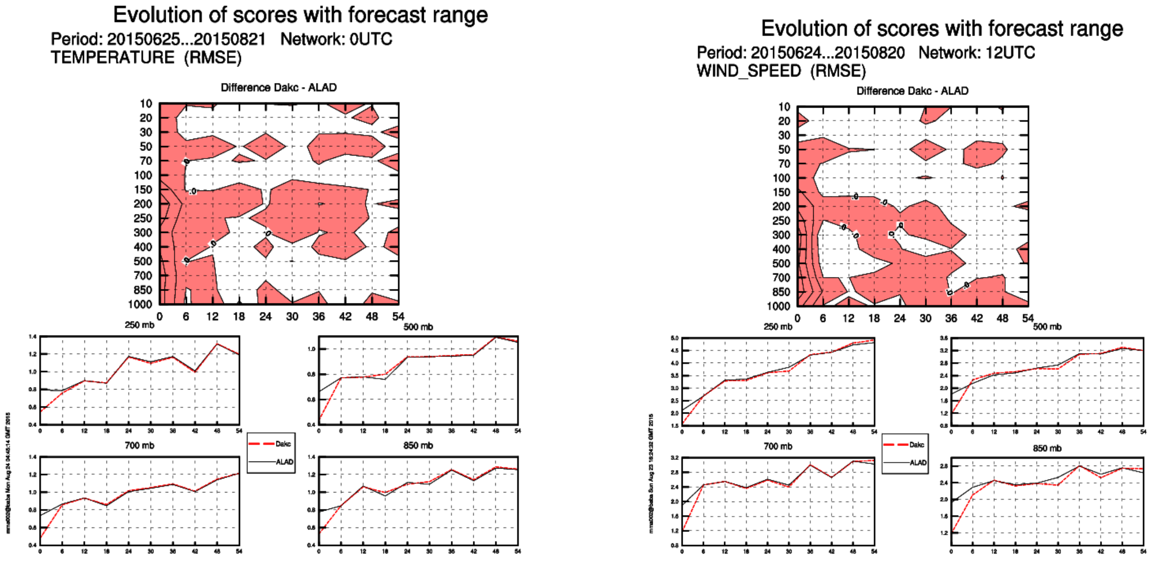

Fig 5: RMSE differences BlendVar (akc) - reference (operational suite) of temperature and wind speed, red areas denote positive impact of BlendVar scheme.

4 Technical notes

The 3D-Var scheme is consuming about 6.5 min in our environment (on 12 CPU of NEC SX-9) and new physics ALARO-1 is also increasing computational time. High optimization of scripts, move of working directories from global file storage to the local hard drives of supercomputer and slight increase of number of processor made time consumption reasonable. The 54 h forecast after all optimization is available only 4 minutes later than version with ALARO-0 and no 3D-Var.

5 Conclusion

Presented BlendVar configuration, combining DF Blending method with the 3D-Var method, improves analysis of high resolution model ALADIN. Although verification against aerological sounding shows only slightly positive to neutral impact, we show improvement of amount and spatial distribution of precipitation over Czech Republic in the case study 1. – 2. June 2013.

Moreover, variational component of BlendVar configuration opens possibilities to use more types of observations, e.g. aircraft Mode-S data, satellite observations, radar observation and other.

Appendix

Surface assimilation changes

Several bugs were identified in the ALADIN at CHMI surface analysis setting, in particular missing TOUCAN interface for the screen level observation, wrong physics namelist for ALARO-1 and missing instantaneous and cumulative fluxes in the assimilation guess, which modulate surface analysis increments (Bellus 2013). The latter has shown significant impact on screen level and 850hPa temperature and humidity bias. The optimum interpolation coefficients for soil moisture analysis depend on soil texture, local solar time and vegetation characteristics. Further more the increments are modulated (mostly decreased) depending on several meteorological fields like precipitation, 10m wind, cloudiness, ice and even the surface moisture increments are set to zero, if surface evaporation is bigger then evapotranspiration or both fluxes are missing in the guess.

Local tests of above mentioned bug-fixes and the default setting of soil moisture increments modulation (ANEBUL=0.75, SPRECIP=.3, V10MX=10.,) showed moist and cold bias in 2m and 850hPa, see Figure 2. Re-tuned soil moisture increments modulation with suppressed influence of precipitation, wind speed and cloudiness (ANEBUL=0., SPRECIP=10000, V10MX=10000.) is now operational to avoid too cold and moist bias in 2m and 850hPa.

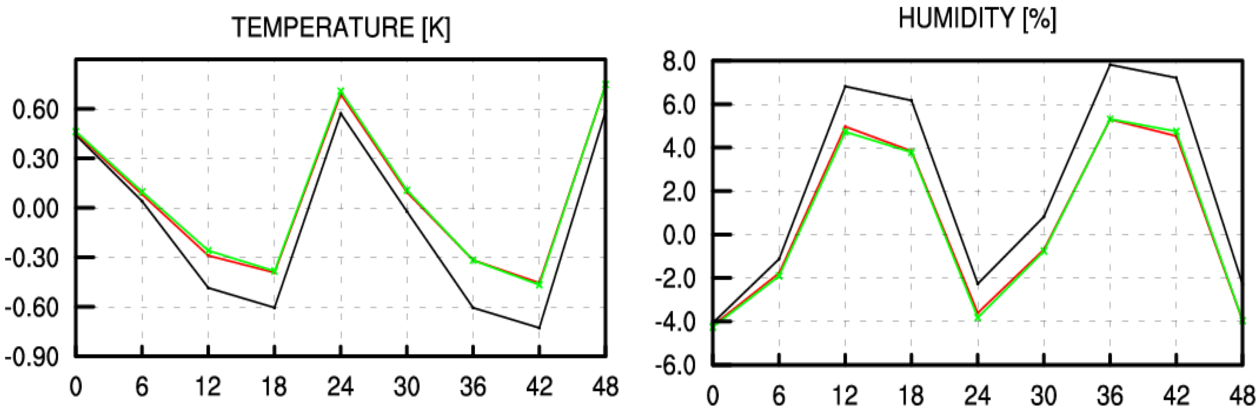

Figure 2: BIAS of T2m and RH2m for 1-10 May 2015 of 00UTC runs. Experiment without all fluxes in assimilation guesses in red, with all fluxes (and the default setting of soil moisture increments modulation) in black and with all fluxes and suppressed modulation by cloudiness, precipitation, v10m and ice (ANEBUL=0, SPRECIP=10000, V10MX=10000, SICE=10000) in green.

Further, one more bug was identified and corrected. Moist gustiness parametrization simulates the influence of precipitation on turbulent diffusion. Unfortunately the precipitation flux is not available in the surface analysis. Moreover, the current code is not bit-reproducible on more processors as precipitation fluxes are not correctly initialized. Thus the moist gustiness parametrization was suppressed in surface analysis. Operational namelists are available on LACE web page http://www.rclace.eu/?page=36).

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