Regional Cooperation for
Limited Area Modeling in Central Europe

LACE
nwp central europe

LAM-EPS activities in RC LACE

Martin Belluš with contributions of **M. Imrišek, Ch. Wittmann, C. Wastl, I. O. Plenković, M. Szűcs and E. Keresturi**

DHMZ

ARSO METEO
Slovenia

ZAMG

ROMANIA ANM

RC LACE Predictability Area - two main subjects:

Predictability

Dynamics

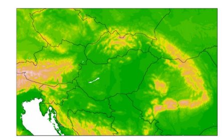
Physics

Data assimilation

AROME-EPS

Δx = 2.5 km

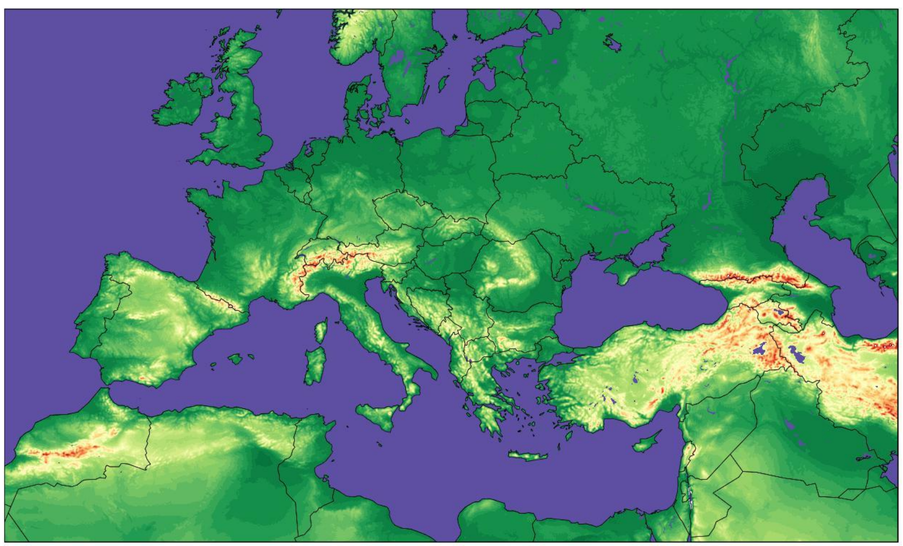
@ ZAMG



@ OMSZ

ALADIN-LAEF

Δx = 11 → 5 km



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- **ALADIN-LAEF**
  - **B-Matrix for new ALADIN-LAEF**
  - **Validation of ENS 3DVar within ALADIN-LAEF Phase II**
  - **Operational ecFlow suite for new ALADIN-LAEF**
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  - **3D version of Stochastic Pattern Generator (SPG)**
  - **Analog-based post-processing method**
  - **Jk 3DVar method**
- **Future Plans**

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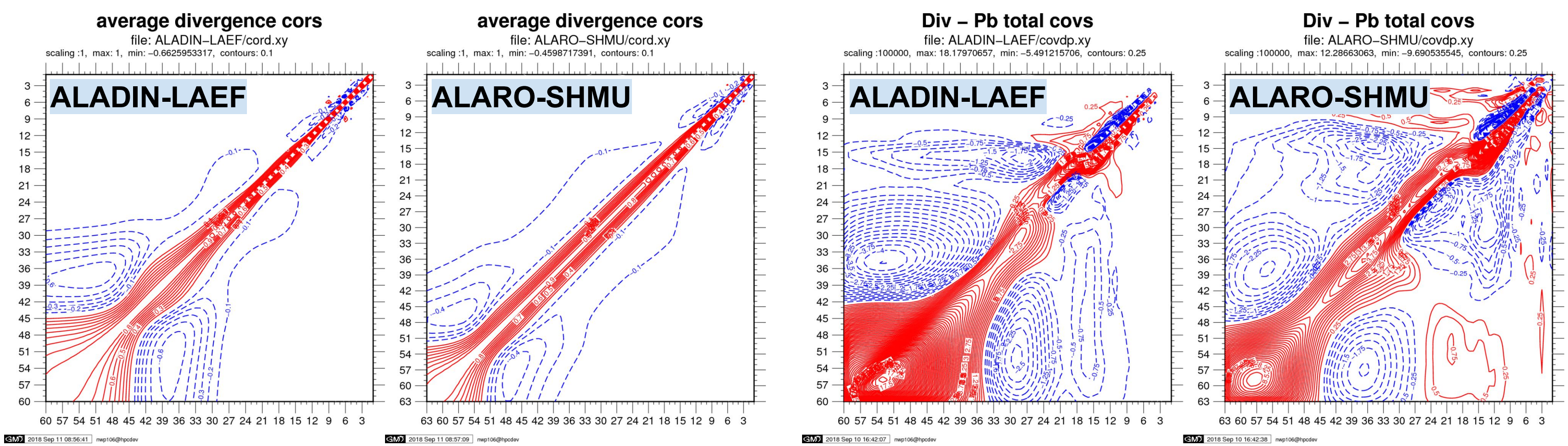
B-Matrix for new ALADIN-LAEF

Creation and diagnostics

Local work at SHMU (M. Belluš)

- different possibilities for background error statistics computation
- flow dependent B-matrix re-computed on daily bases
- standard ensemble approach for B-matrix computation
- B-matrix based on 256 samples (5 km, 60 levels, ALARO-1 physics, Phase I configuration)
- 12h forecasts from both 00 and 12 UTC network times
- cycle 40t1 with the latest bugfix involving the correction of scaling factor in nmcstat.F90
- the diagnostics were qualitatively compared against the equivalent B-matrix (ALARO-SHMU)

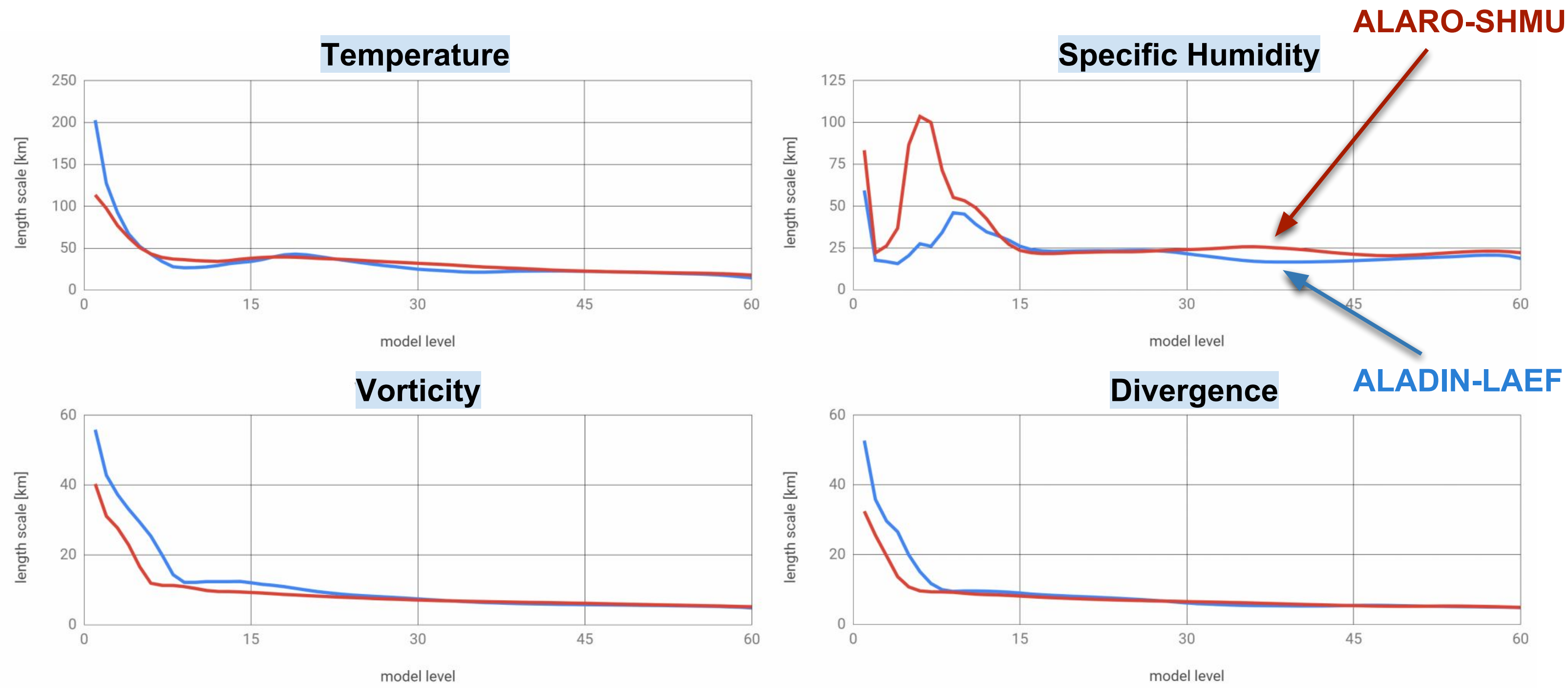


Mean vertical correlation of divergence (left) and mean vertical cross-covariance between divergence and vorticity-balanced geopotential (right) for ALADIN-LAEF 4.8 km / 60 lev vs ALARO-SHMU 4.5 km / 63 lev.

B-Matrix for new ALADIN-LAEF

Creation and diagnostics

- spatial propagation of the increments is important feature of the assimilation procedure
- it happens in accordance with given length scales

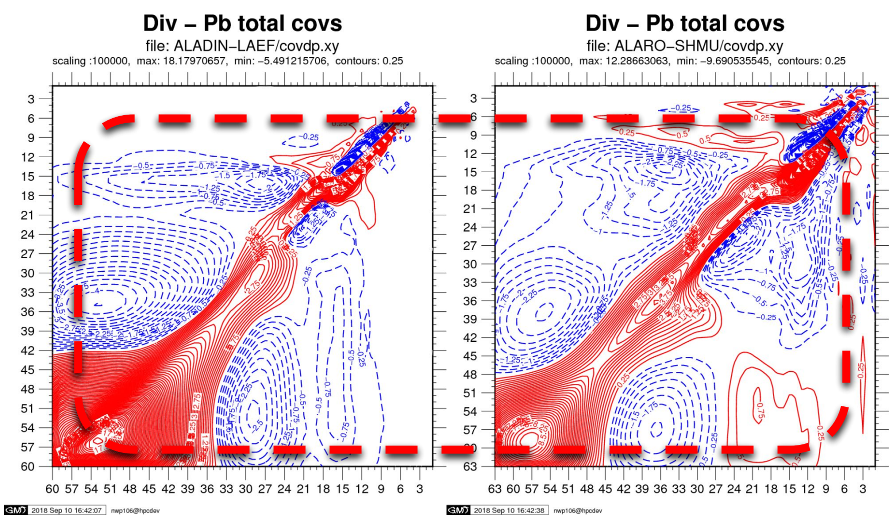


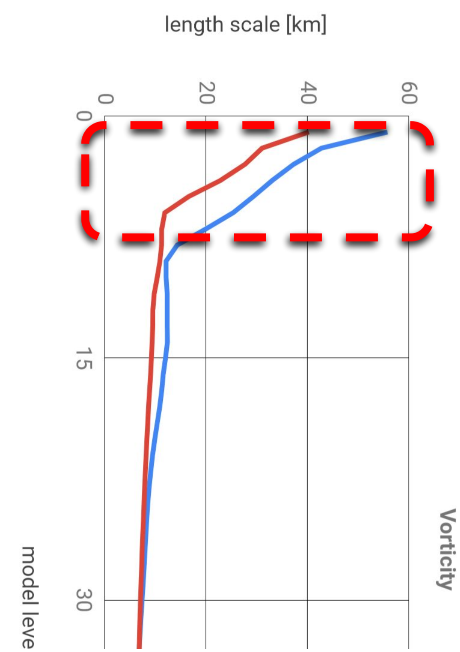
Vertical profile of length scales for temperature (top left), specific humidity (top right), vorticity (bottom left) and divergence (bottom right) for ALADIN-LAEF 4.8 km / 60 lev (blue) and ALARO-SHMU 4.5 km / 63 lev (red).

B-Matrix for new ALADIN-LAEF

Conclusions

- physical coupling between the variables is apparently characterized by similar patterns
- vertical profiles of length scales for different parameters are qualitatively comparable
- discrepancy of length scales at the models’ top (different layouts of vertical levels: L60 vs L63)
- we have considered our B-matrix suitable for sensitivity and validation experiments
- it has been used in the validation of ENS 3DVar within ALADIN-LAEF Phase II





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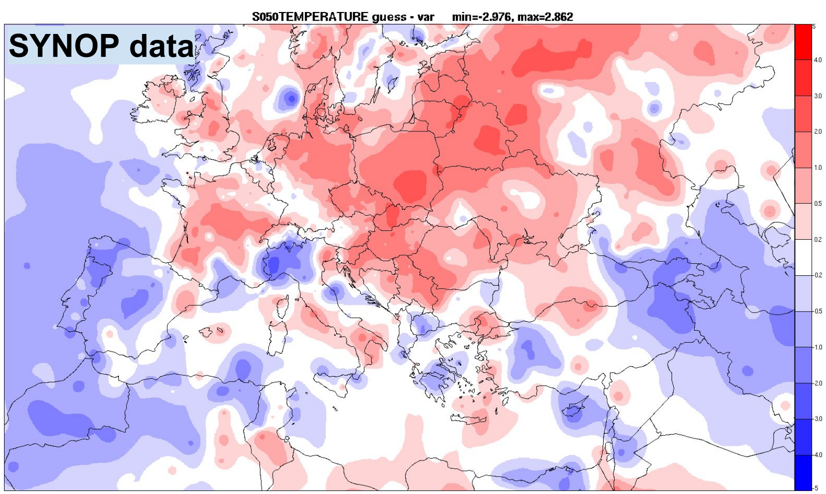
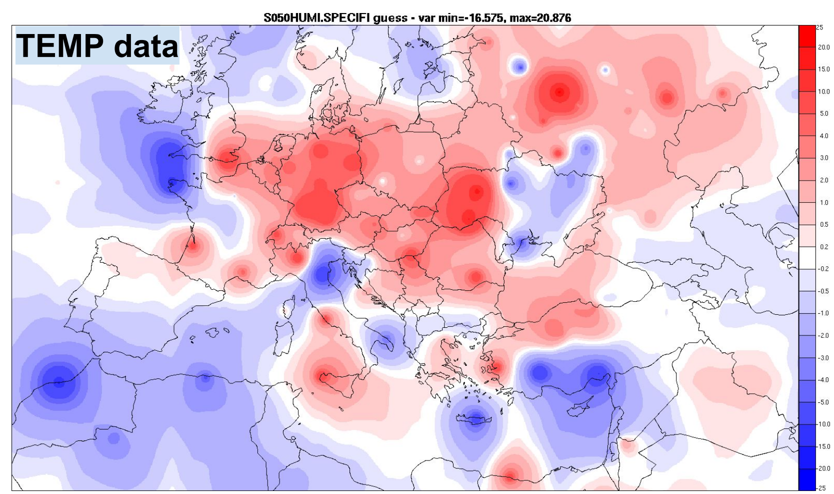
Validation of ENS 3DVar within ALADIN-LAEF Phase II

Implementation of various data

RC LACE Stay at ZAMG (M. Imrišek)

- new method for handling IC perturbation of the upper-air fields (ENS BlendVar)
- it should replace currently used breeding-blending approach
- it is meant to enter the new ALADIN-LAEF Phase II (later in 2019)
- various data types were implemented into the 3DVar of new ALADIN–LAEF system
- SYNOP, TEMP, AMDAR, GEOWIND (OPLACE) and GNSS zenith total delay (SUT)



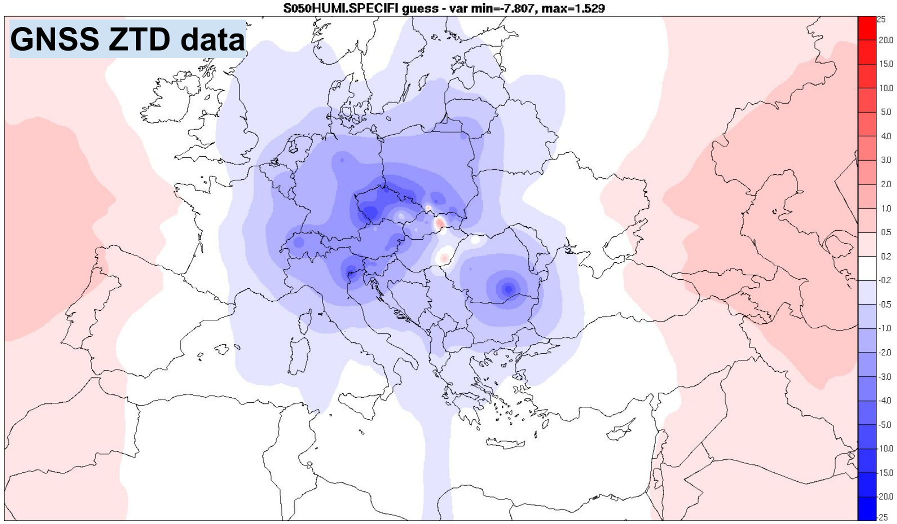


Temperature increments for SYNOP-only data assimilation (left) and specific humidity increments for TEMP-only data assimilation (right), both at the 50th model level.

Validation of ENS 3DVar within ALADIN-LAEF Phase II

GNSS zenith total delay

- whitelist for GNSS permanent stations had to be assembled
- **first approach** - the combination of all first guess departures for all members and all terms (this turned to be inappropriate - Pearson's Chi-squared test rejected too many station)
- **second approach** - each member tested separately (5-12 rejected stations per member)
- **third approach** - all members tested together just for one day with Jarque–Bera test (different amount of stations rejected for given day)
- based on these results it was decided to use best day (with all members and lowest amount of rejected stations) and best member (with all days and lowest amount of rejected stations) together for whitelist estimation

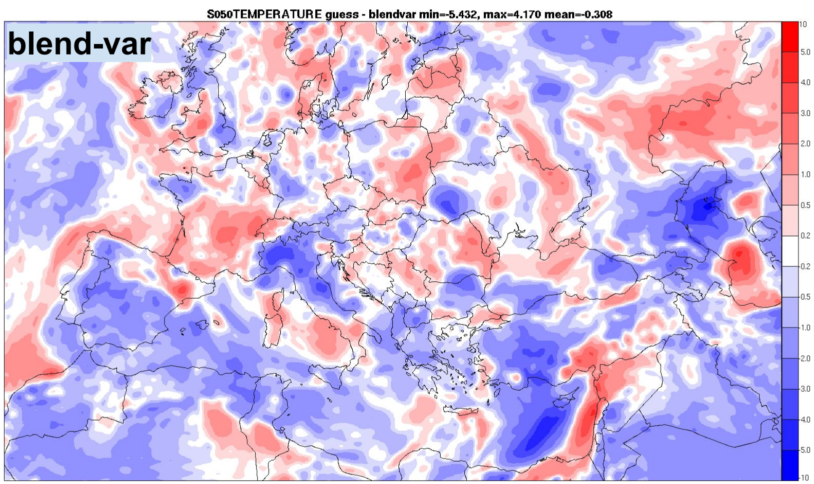


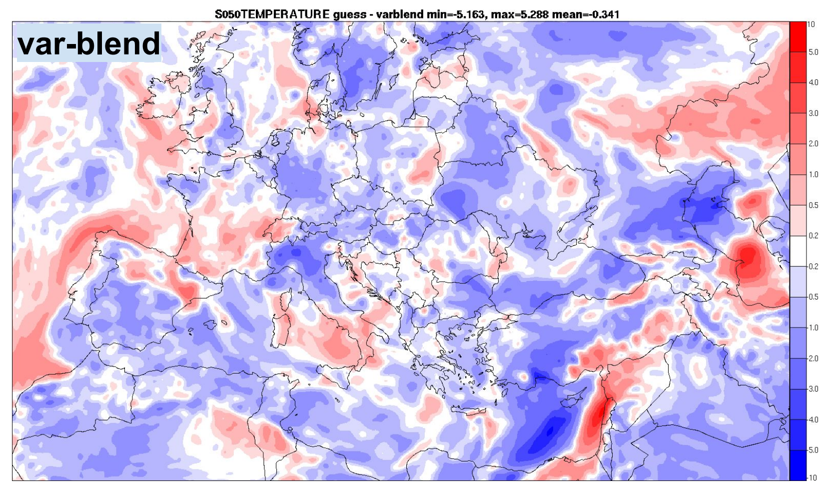
Specific humidity increments at 50th model level for GNSS-only (zenith total delay) data assimilation.

Validation of ENS 3DVar within ALADIN-LAEF Phase II

IC perturbation

- random Gaussian perturbation was applied to all data using internal function of "screening"
- ALADIN-LAEF experiment with switched-on 3DVar (**Phase II**) was verified against ALADIN-LAEF experiment without 3DVar (**Phase I**)
- there were in principle two possibilities how to incorporate 3DVar into the existing ALADIN-LAEF data flow
- two experiments with all available data were carried out, i.e. the "blend-var" and "var-blend" configurations
- in **blend-var** clearly dominates the effect of assimilation
- in **var-blend** the gradients in temperature increments are smaller (model fields are also smoother due to the digital filtering involved in blending)



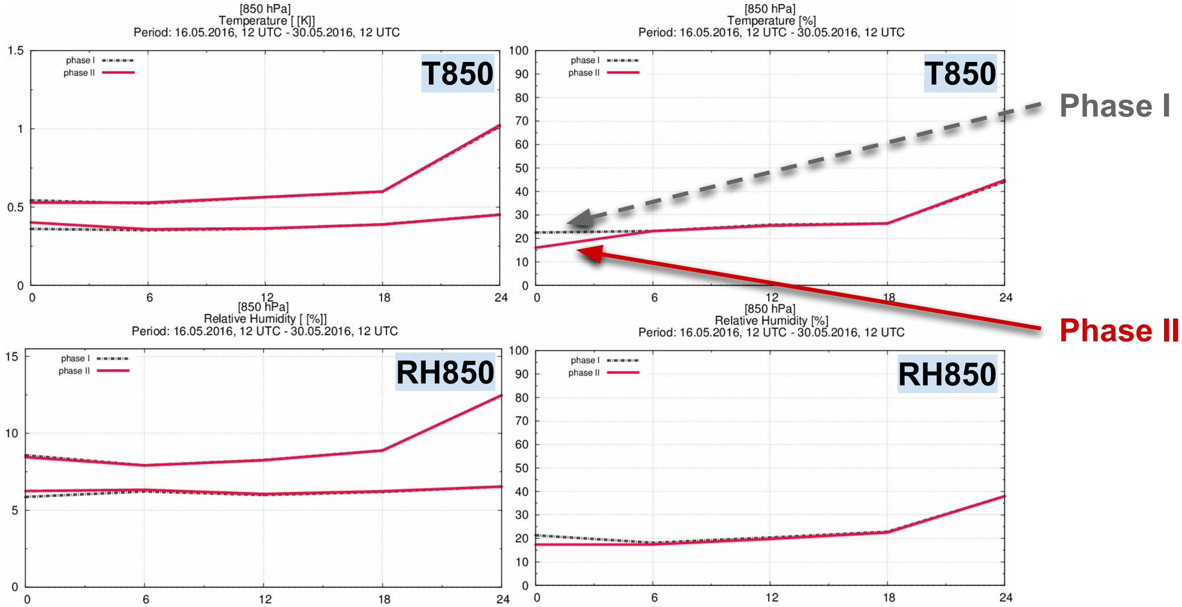


Temperature increments at 50th model level in the initial conditions (IC) created by blend-var configuration (left) and var-blend configuration (right).

Validation of ENS 3DVar within ALADIN-LAEF Phase II

Conclusions

- according the expectations, the impact is rather small but positive
- ensemble spread slightly increased while RMSE little bit decreased (for the very first hours)
- decrease of outliers for both temperature and relative humidity
- impact on wind field can be considered rather neutral
- slight degradation of the scores for geopotential (depending on vertical height)



RMSE and SPREAD (left) and OUTLIERS (right) for temperature (top) and relative humidity (bottom) at 850 hPa level. The Phase I scores (grey dashed lines) and Phase II (red lines).

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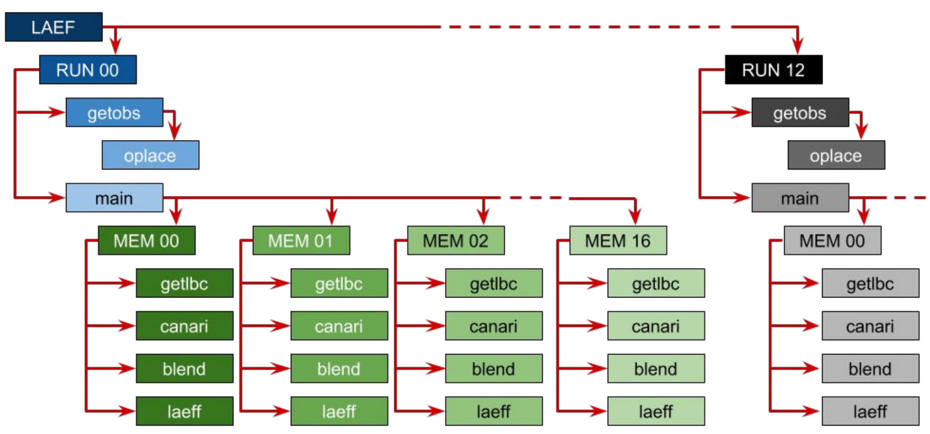
Operational ecFlow suite for new ALADIN-LAEF

Built from scratch

RC LACE Stay at ZAMG (M. Belluš)

- current ALADIN-LAEF system runs from the beginning of its operations under SMS (becoming obsolete)
- SMS is being replaced by ecFlow (object oriented, standardised components)
- proprietary scripting language used by SMS (CDP) has been replaced by Python
- current ALADIN-LAEF suite has not been technically updated for several years
- decision to start building new suite from scratch (rather than converting the old one from SMS to ecFlow)
- another reason - quite big difference between the “current” and currently developed ALADIN-LAEF components
- new ecFlow suite was prepared at ECMWF HPCF (Python + Perl)

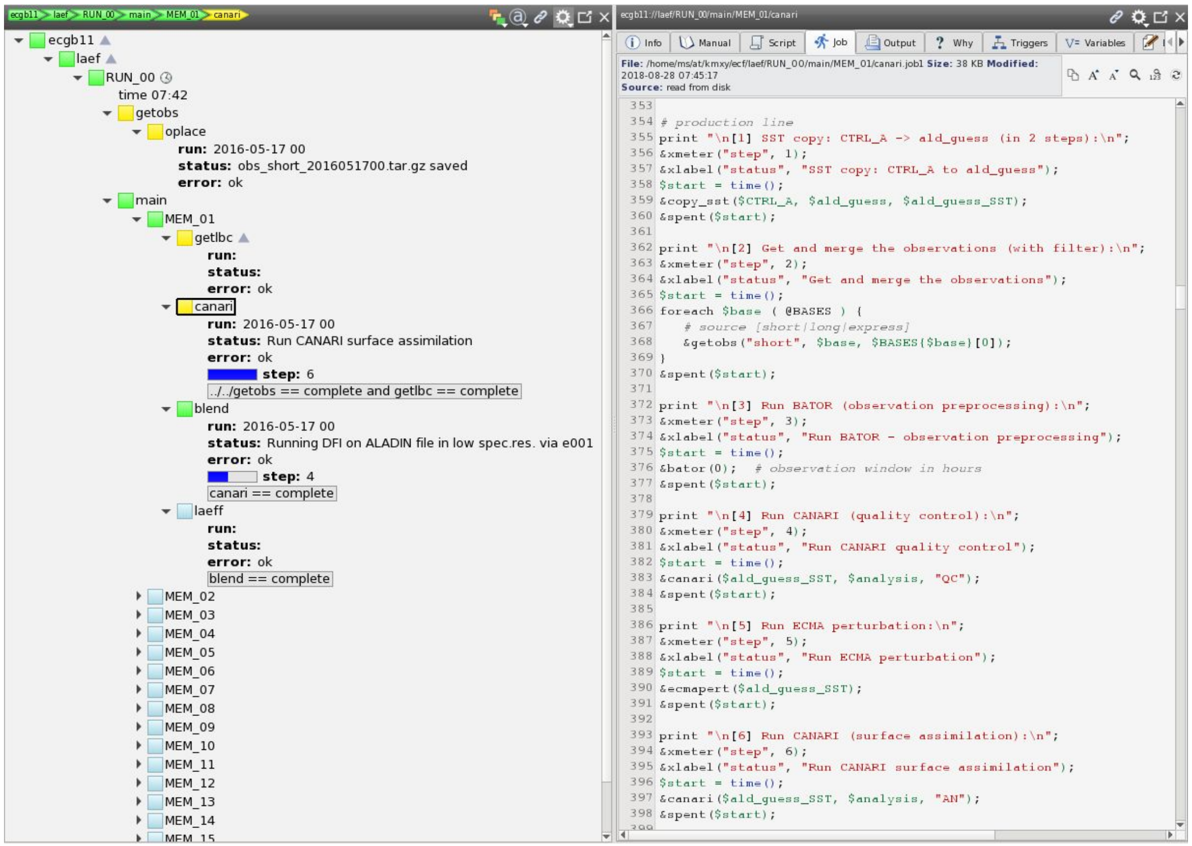
ALADIN-LAEF	current	new
Code version	cy36t1	cy40t1
Horizontal resolution	10,9 km	4,8 km
Vertical levels	45	60
Number of grid points	500x600	750x1250
Grid	quadratic	linear
Time step	450 s	180 s
Forecast length	72 h (00/12 UTC)	72 h (00/12 UTC)
Members	16+1	16+1
IC perturbation	ESDA [surface], breeding-blending [upper-air]	ESDA [surface], blending (Phase I) / ENS BlendVar (Phase II) [upper-air]
Model perturbation	ALARO-0 multi-physics	ALARO-1 multi-physics + surface SPPT
LBC perturbation	ECMWF ENS	ECMWF ENS
SBUs consumed per year	~10 mil	~120 mil



ALADIN-LAEF system specifications for current and new version (left) and Phase I flow chart (right). Phase I is expected to become pre-operational till the end of 2018.

Operational ecFlow suite for new ALADIN-LAEF

Phase I under ecFlow GUI



New ALADIN-LAEF suite (Phase I) under the ecFlow environment (ecFlow GUI screenshot). Suite definition file is generated by Python code, while all tasks, include files and configuration modules are written in Perl.

Operational ecFlow suite for new ALADIN-LAEF

Phase I uncertainty simulation

ESDA:

$$\Delta T_s = \Delta T_{2m} \qquad \Delta W_s = \alpha_s^T \Delta T_{2m} + \alpha_s^H \Delta H_{2m}$$

$$\Delta T_p = \frac{1}{2\pi} \Delta T_{2m} \qquad \Delta W_p = \alpha_p^T \Delta T_{2m} + \alpha_p^H \Delta H_{2m}$$

BLENDING:

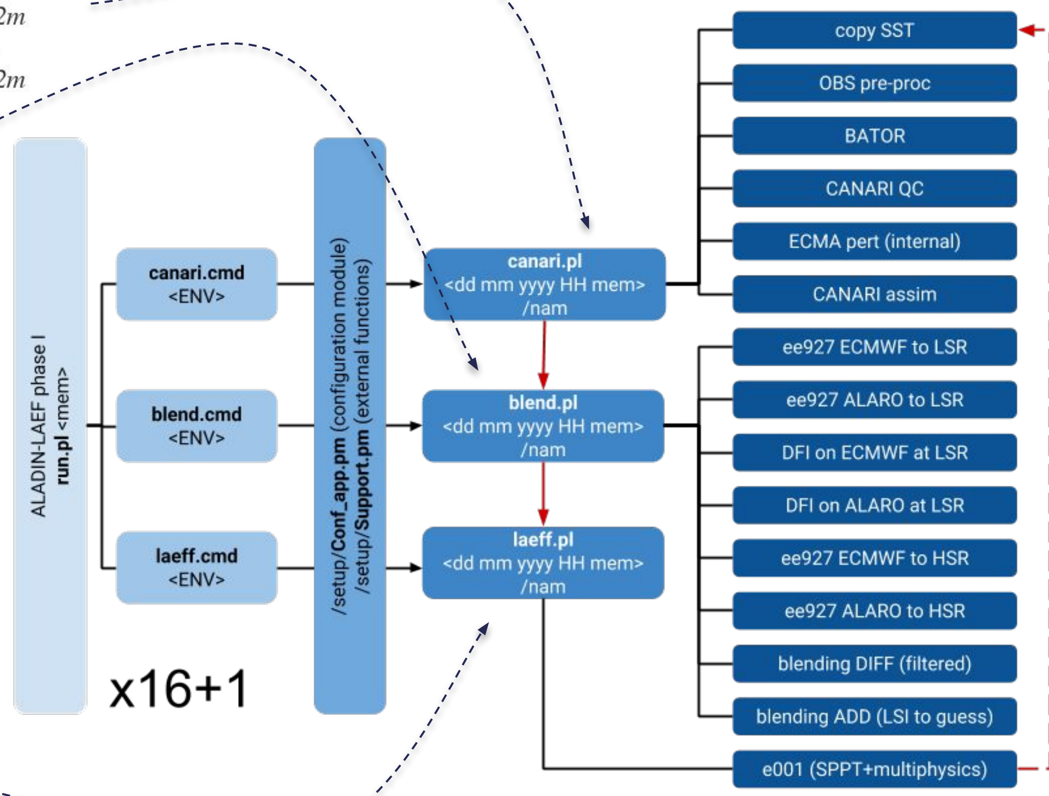
$$IC_{blend}^n = a_{breed}^n + \{ \overline{(a_{sv}^n)_{trunc}} - \overline{(a_{breed}^n)_{trunc}} \}$$

$$IC_{blend}^n = LS^n + a_{breed}^n$$

SPPT + MP:

$$\frac{\partial e_j}{\partial t} = A(e_j,t) + P'(e_j,t)$$

$$P'_j(e_j,t) = (1 + r_j(\lambda,\varphi,t)_{D,T}) P_j(e_j,t)$$



DHMZ ARSO METEO Slovenia ZAMG ROMANIA ANM

Operational ecFlow suite for new ALADIN-LAEF

Phase I uncertainty simulation

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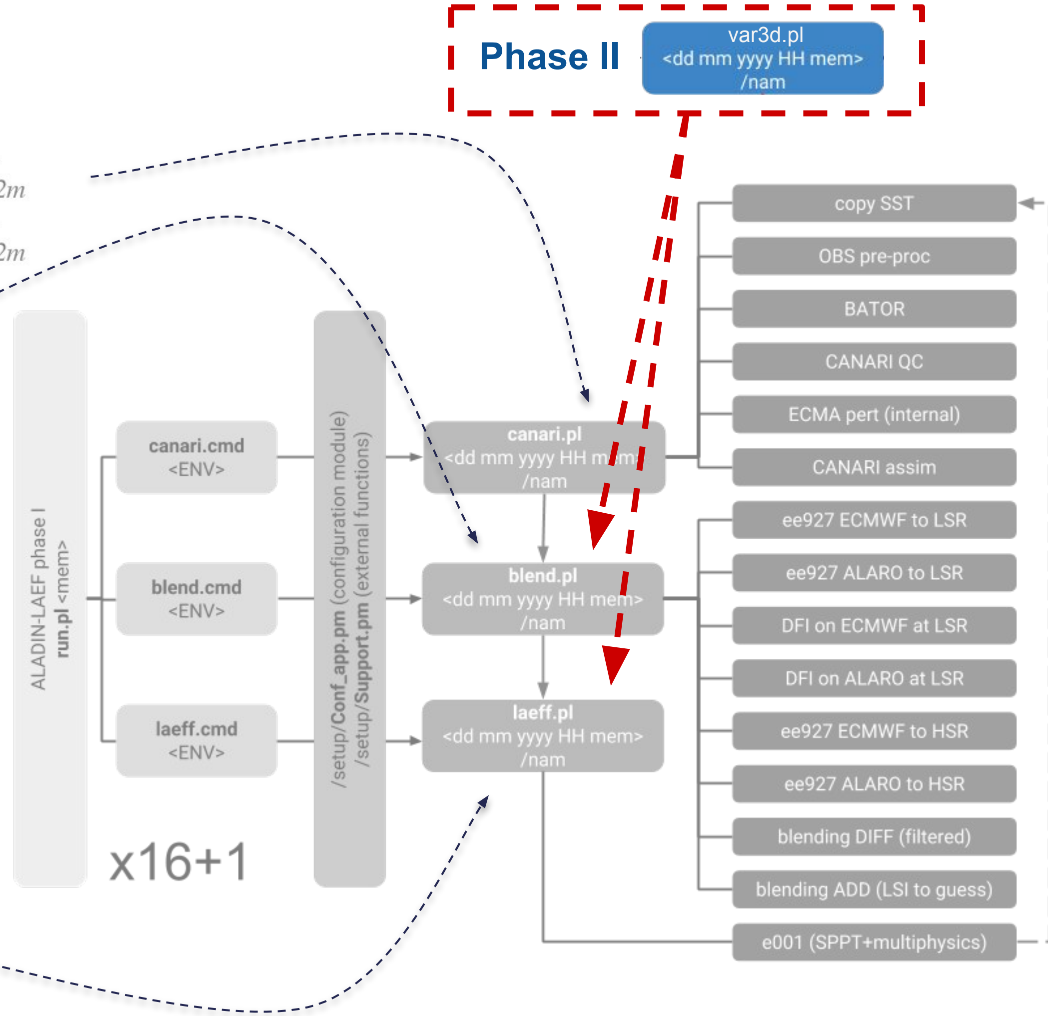
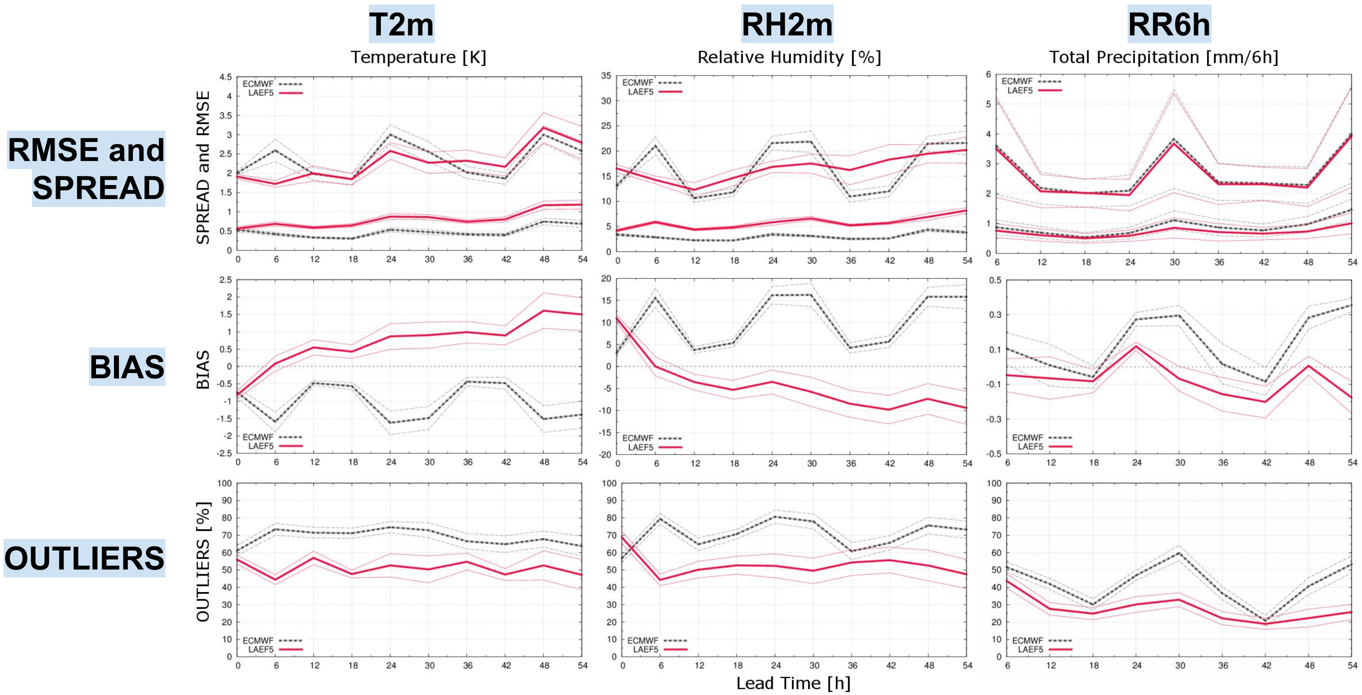


Operational ecFlow suite for new ALADIN-LAEF

Phase I scores

The added value of new ALADIN-LAEF over the downscaled ECMWF ENS is obvious for the surface parameters, while it is rather neutral in the upper-air.



ALADIN-LAEF phase I (red lines) and ECMWF-EPS downscaling (gray dashed lines) for surface parameters. The thin lines denote 10% and 90% confidence intervals for given experiment.

Operational ecFlow suite for new ALADIN-LAEF

Conclusions

Was done:

- Python API allows the entire suite definition structure to be specified, checked and loaded into the ecFlow server
- on-the-fly generated ALADIN-LAEF suite definition file has over 1.3k lines (Python script only 244)
- we were able to use existing new LAEF Perl “bricks” as native ecFlow tasks
- some modifications needed to involve necessary ecFlow client communication
- this counts all together more than 3k lines of reusable code
- first functional suite was created and tested under kmxy user at ecgate

Next steps:

- next steps towards TC application need to be done in cooperation with the user support at ECMWF
- new suite must be tested under TC environment under LACE operational account “zla”
- new products must be specified and set-up (also their distribution to the partners)
- pre-operational run in parallel with the old ALADIN-LAEF suite is highly desirable

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EPS related development at OMSZ and ZAMG

Operational changes at OMSZ

- primarily focusing on their future convection-permitting EPS
- new machine devoted to such purpose has already arrived
- they progress slowly with the migration to new HPC
- the installation of AROME-EPS on new system in the next months is of highest priority
- new system will fully replace current 8 km version of ALARO-EPS

Operational changes at ZAMG

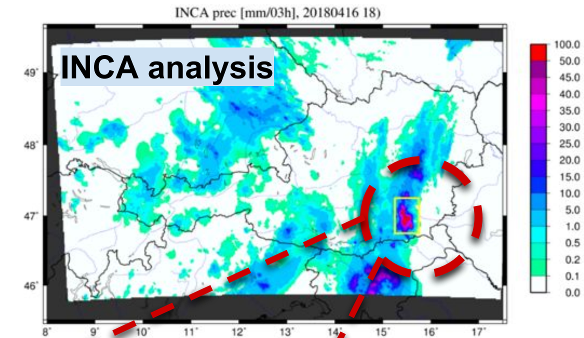
- no operational changes in local EPS (new HPC, missing manpower)
- initial C-LAEF configuration (till the end of this year)
- translation of the system and scripts into the ecFlow
- pre-operational runs are expected next year (at ECMWF HPCF)

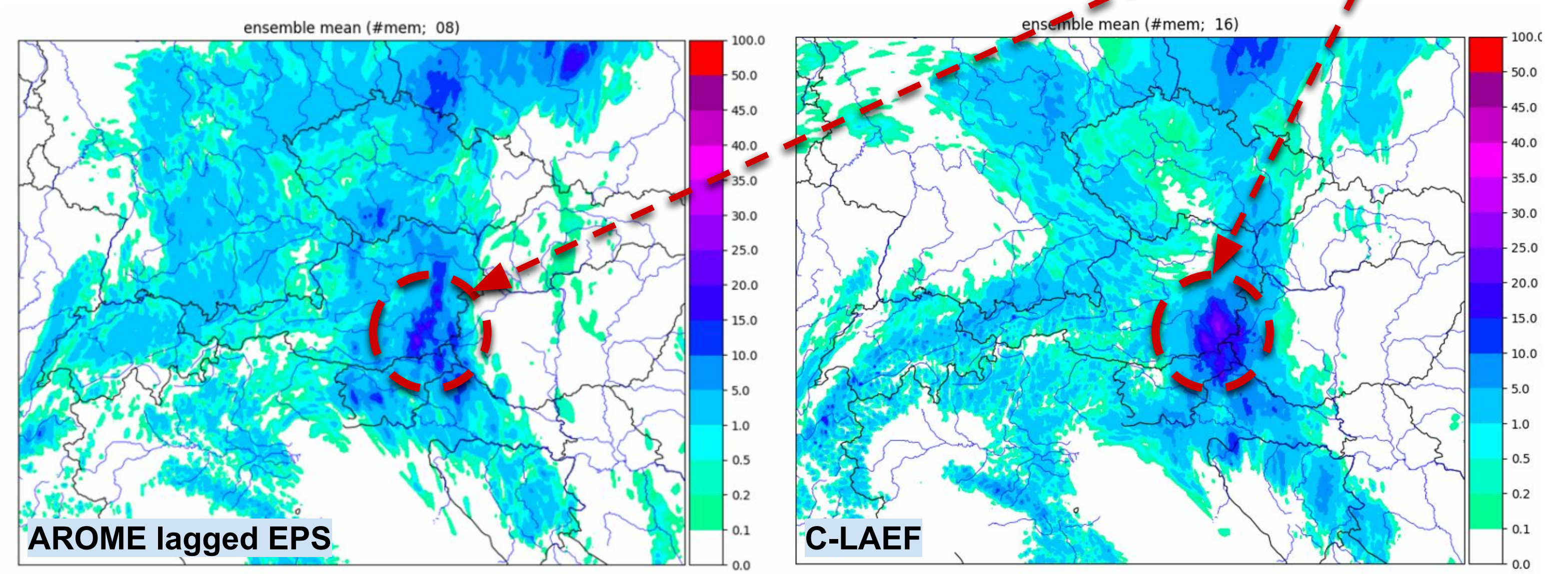
EPS related development at ZAMG

Case study with C-LAEF

Extreme convection event case study (Ch. Wittmann)

- Graz, April 16, 2018
- precipitation intensity up to 100 mm in 3h (locally even more)
- potential benefit of C-LAEF with respect to the pseudo-EPS
- C-LAEF (16 members), only downscaling with SPPT
- pseudo-EPS (8 AROME deterministic runs - lagged EPS)





Extreme precipitation event from April 16, 2018. The ensemble mean of 3-hourly accumulated precipitation for AROME pseudo-EPS (left) and C-LAEF (right). INCA precipitation analysis [mm/3h] (top).

EPS related development at ZAMG

C-LAEF development

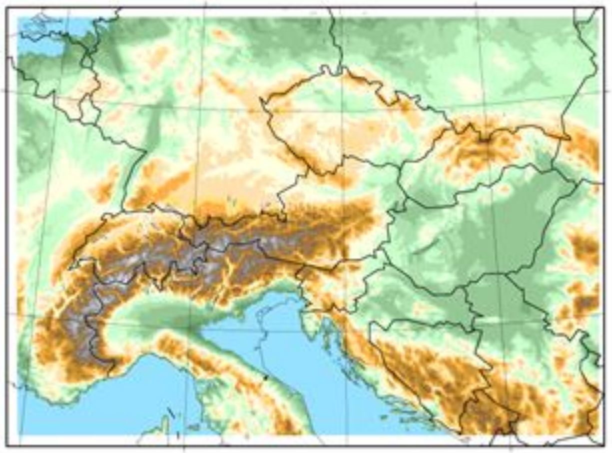
C-LAEF development (C. Wastl)

- C-LAEF is convection-permitting EPS currently under development at ZAMG
- contains representation of all uncertainties in NWP (IC, LBC, model error)
- stochastic physics is used to increase spread and reduce RMSE (lower levels)
- perturbing partial tendencies of physics schemes (pSPPT) increases stability of the model
- different stochastic pattern scales used for shallow convection, radiation, turbulence, microphysics
- thanks to increased stability => tapering function is not needed (except for turbulence)
- combination of tendency perturbations and parameter perturbations (SPP)
- tendency perturbation of turbulence has been replaced by parameter perturbations
- parameters like dissipation rate, mixing length, correlation factors are perturbed

Convection permitting Limited Area Ensemble Forecasting	
AROME based; under development - not yet operational; ECMWF supercomputer	
ensemble size	16 + 1
Δx / vertical levels	2.5 km / 90
coupling	ECMWF-ENS
runs per day	2 / 4 runs (+30 h forecast)

Initial conditions error + **Lateral boundary conditions error** + **Model error**

Initial conditions error	Lateral boundary conditions error	Model error
Ensemble-data assimilation (EDA) Ensemble-data assimilation of surface variables (sEDA)	Ensemble-JK	Perturbation of tendencies (SPPT, pSPPT) Perturbation of parameters (SPP) Combination of pSPPT+SPP (HS)



C-LAEF computational domain.

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3D version of Stochastic Pattern Generator (SPG)

Implementation

RC LACE Stay at ZAMG (M. Szűcs)

- work covers 3D extension of new SPG
- current SPG implementation allows only vertically constant 2D random patterns
- now prognostic fields can be perturbed in all 3 dimensions
- short sensitivity study with the new method was carried out
- work is still in progress

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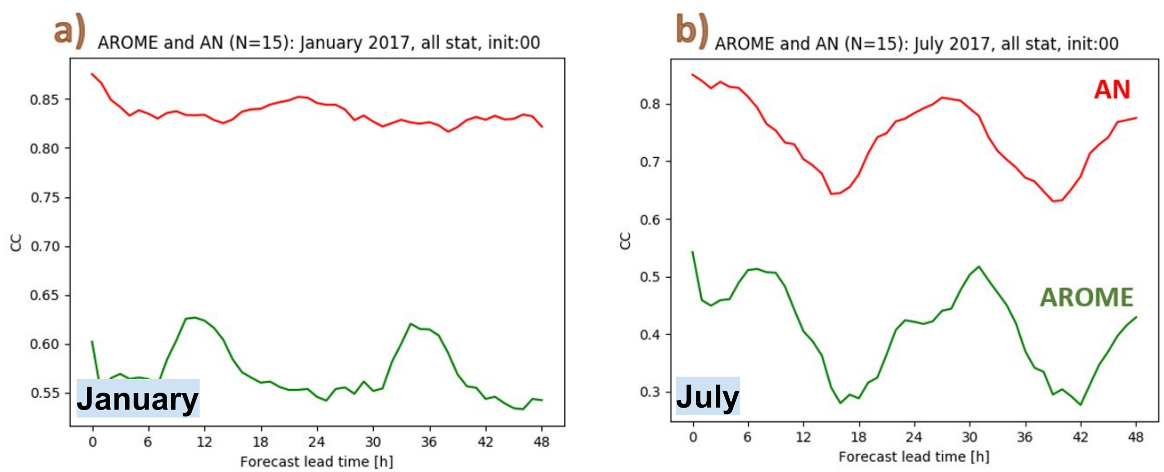
Analog-based post-processing method

Wind speed

RC LACE Stay at ZAMG (I.O. Plenković)

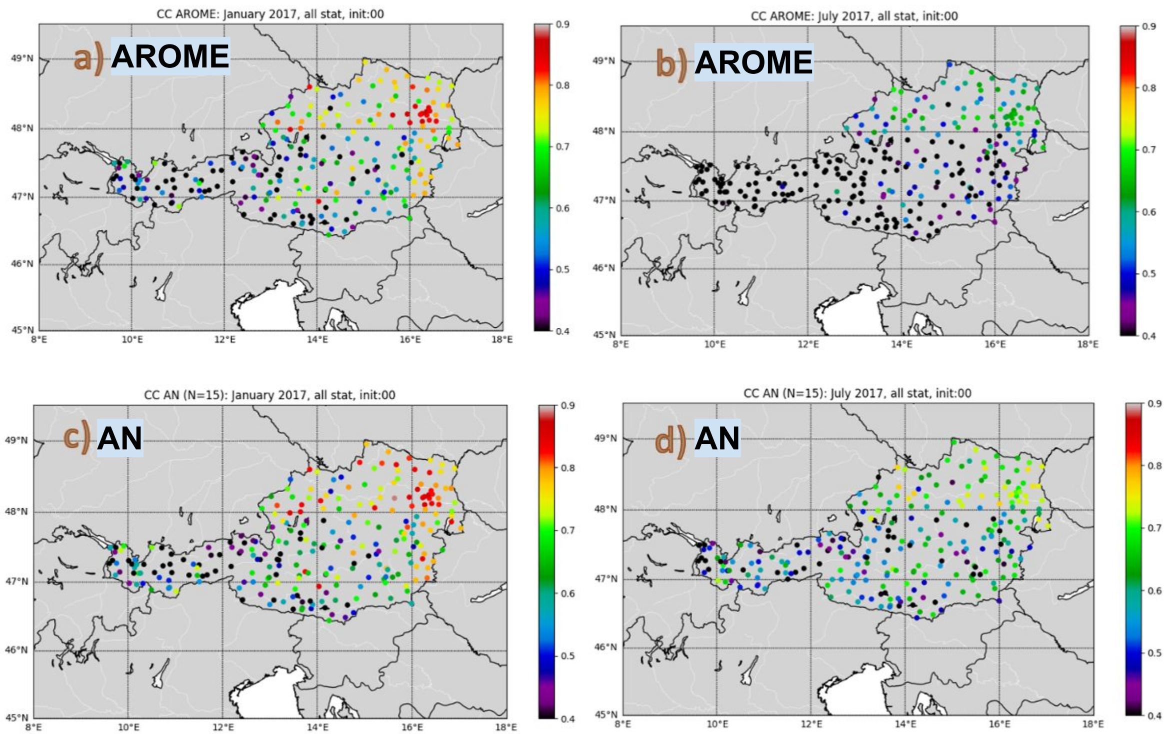
- point-based analog-based post-processing method applied to a NWP model output
- special attention was put into Python code optimization making the algorithms more efficient
- testing the analog-based post-processing method at least on one deterministic model (AROME)
- algorithm was tested for two months: January 2017 (winter) and June 2017 (summer)
- the same training period (2015-2016) and the same setup for both
- analog ensemble mean forecast (AN) was computed as the average of 15 analog ensemble members



The wind speed forecast correlation coefficients for AROME (green line) and analog ensemble mean AN (red line) for January (left) and July (right) 2017.

Analog-based post-processing method

Wind speed



The spatial distribution of the monthly mean correlation coefficients for AROME (a, b) and analog ensemble mean AN (c, d) forecast in the January (left) and July (right), 2017.

Analog-based post-processing method

Conclusions

It was shown that the analog-based approach compared to the AROME forecasts has:

- distribution closer to the observed distribution
- smaller bias
- higher correlation coefficients to the observations
- lower RMSE

Next steps:

- develop and test the probabilistic output for the AROME data
- use ECMWF model for both deterministic and probabilistic approach
- use at least two deterministic models as input ("poor-man ensemble")
- use LAEF ensemble as input and compare the results

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Jk 3DVar method

IC perturbation

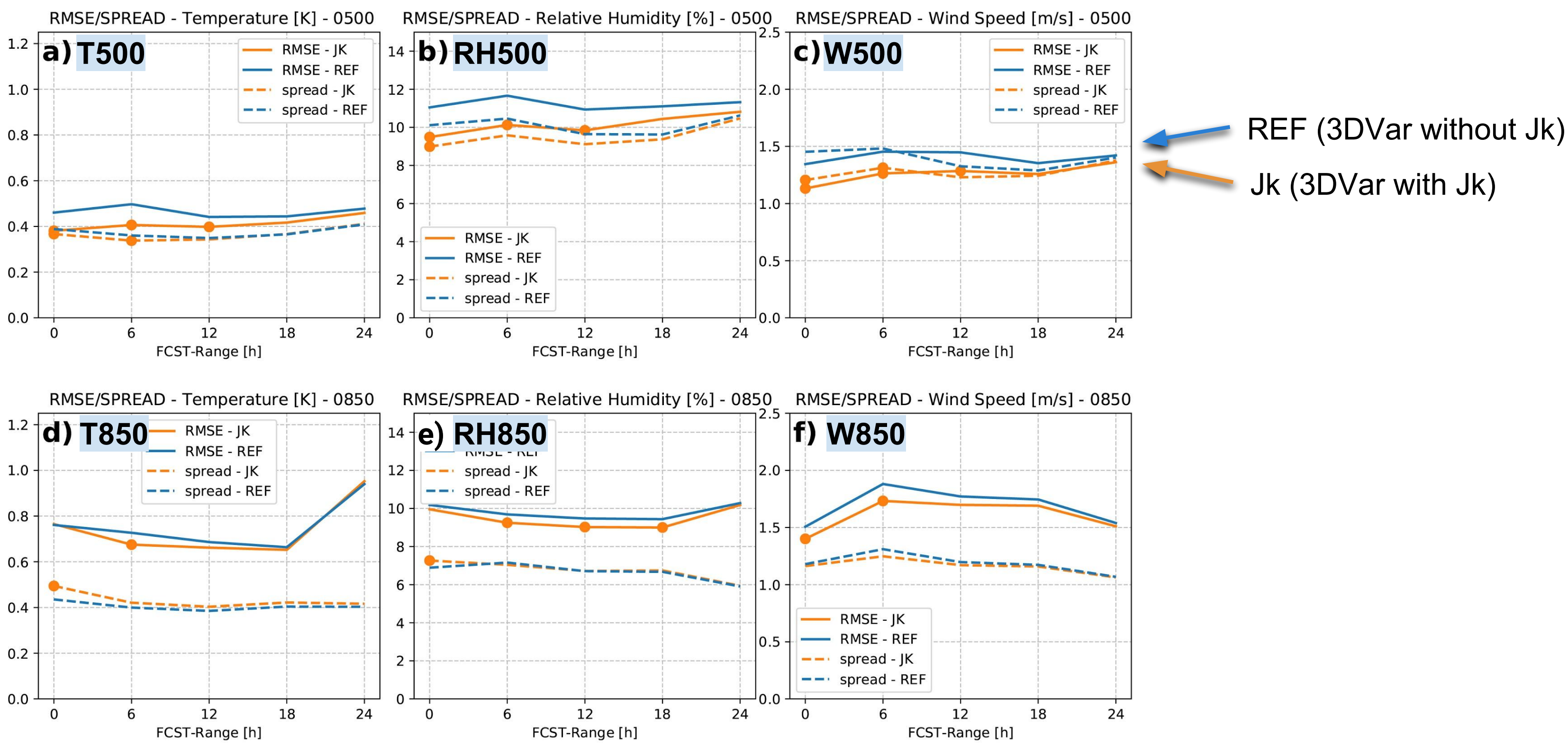
PhD Stay at ZAMG - until March 2018 (E. Keresturi)

- general idea like spectral blending but technically different
- global model information is included directly into LAM variational assimilation (Jk term)
- combination of large scale (GM-EPS) and small scale (LAM-EPS) perturbations
- consistent IC and LBC perturbations in convection-permitting EPS
- previous experiment was extended by one month (July-August 2016) => more significant results
- paper was submitted into Quarterly Journal of the Royal Meteorological Society

Reference: Keresturi E., Y. Wang, F. Meier, F. Weidle, Ch. Wittmann, 2018: "***Improving initial condition perturbations in a convection permitting ensemble prediction system***", submitted to Quarterly Journal of the Royal Meteorological Society, (*currently under second review*)

Jk 3DVar method

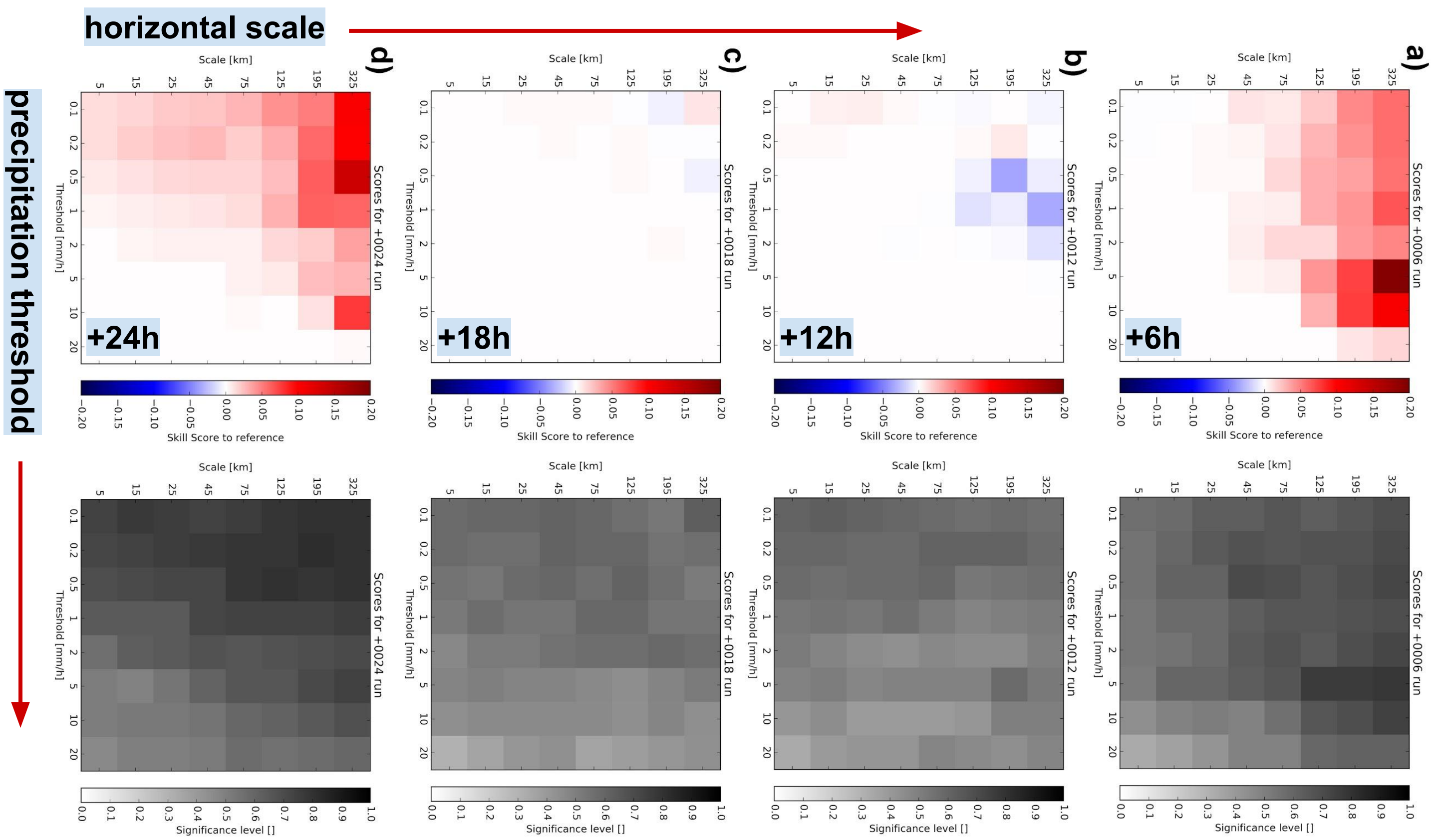
Upper-air verification July-August 2016



RMSE of ensemble mean (solid lines) and ensemble spread (dashed lines) of REF (AROME-EPS with 3DVar without Jk term) - blue and Jk - orange for (a) T500; (b) RH500; (c) W500; (d) T850; (e) RH850 and (f) W850. The verification period is July-August 2016. Forecast ranges with statistically significant differences are marked with a bullet symbol.

Jk 3DVar method

Precipitation verification July-August 2016 (Fractions Skill Score)



The median skill score of FSS (top) and significance level (bottom) for the comparison of Jk blending and the reference (AROME-EPS with 3DVar without Jk term) as a function of lead time (a) +6; (b) +12; (c) +18 and (d) +24 hours. Horizontal scales on y-axes and precipitation thresholds on x-axes.

Jk 3DVar method

Conclusions

500 hPa level

- positive impact on the ensemble error
- the impact on ensemble spread is not that clear
- at 500 hPa the spread has been even decreased
- significant reduction of RMSE
- ratio between RMSE and spread is clearly improved

850 hPa level

- at 850 hPa significant decrease of RMSE
- only slight increase of ensemble spread (beginning hours)

Surface

- neutral impact at the surface

Precipitation

- verified using fractions skill score (FSS)
- comparison between the FSS of Jk blending and the reference (AROME-EPS with 3DVar without Jk term)
- +6h: forecast improved for all thresholds (scales >195 km) and for thresholds <5 mm (scales above 45 km)
- +12h and 18h: neutral results
- +24h: forecast improved for all scales (threshold of 1 mm) and for higher thresholds (scales >195 km)

Future plans (RC LACE Predictability Area) 1/2

The main goals in 2019 are clearly the pre-operational and operational implementations of new ALADIN-LAEF and C-LAEF systems at ECMWF HPCF as well as the operational implementation of a convection-permitting system on new HPC at OMSZ.

ALADIN-LAEF:

- Use **new SPG pattern generator** to perturb the upper-air fields in ALADIN-LAEF system. Investigate the impact of different tunings and their possible side effects on atmosphere drying or model stability (do we need tapering function?) with respect to the scheme performance.
- Test the impact of regularly recomputed **flow-dependent B-matrix** using the ALADIN-LAEF outputs. Investigate the feasibility of applying such approach on daily bases. Provide input data to the local teams for their own EDA computations. Cooperation with DA group.
- Apply the **analog-based post-processing method** to the ALADIN-LAEF high-resolution wind field ensemble and compare its probabilistic output with the reference. Investigate the possibility to use such a method for the other surface parameters like T2m, RH2m or precipitation and on gridded data.
- Finalize the ALADIN-LAEF 5 km Phase II configuration involving **ENS BlendVar** to simulate the uncertainty of the upper-air ICs. Make important decisions like: blend-var vs var-blend; which OBS types should be used; what cycling frequency to be applied, etc.

Future plans (RC LACE Predictability Area) 2/2

The main goals in 2019 are clearly the pre-operational and operational implementations of new ALADIN-LAEF and C-LAEF systems at ECMWF HPCF as well as the operational implementation of a convection-permitting system on new HPC at OMSZ.

AROME-EPS:

- Combine different methods to simulate the uncertainty of the ICs and model uncertainty in a convection-permitting system (i.e. **stochastic perturbation of partial model tendencies**, **parameter perturbation**, **Jk 3DVar blending**, etc.).
- Investigate the **model stability while stochastic perturbations are applied** in combination with other uncertainty sources, especially when smoothing of the perturbations to the model top and surface is switched off and when 3D version of stochastic pattern generator is used.
- Pre-operational and operational implementation and testing of a convection-permitting ensemble system **C-LAEF** at 2.5 km and 90 vertical levels at **ECMWF HPCF**.
- Pre-operational and operational implementation and testing of a **convection-permitting ensemble** system on new **HPC at OMSZ**.

Thank you for your attention!