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. Szűcs, M. Dian, Ch. Wittmann, F. Weidle, Y. Wang, C. Wastl, S. Taşcu, R. Pomaga and E. Keresturi

DHMZ

SHMU

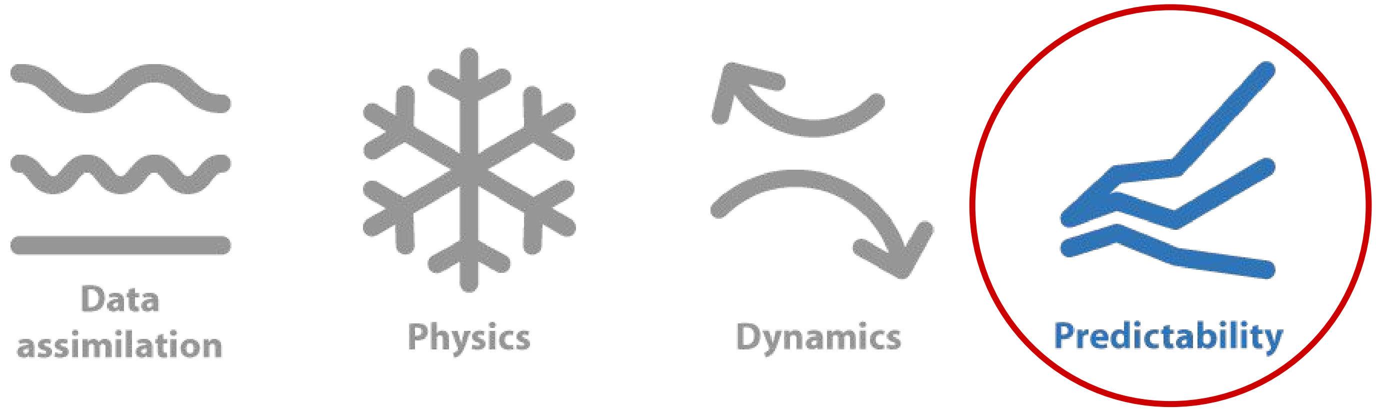
ARSO METEO Slovenia

OMSZ

ZAMG

ROMANIA ANM

Overview of activities (since last EWGLAM)



RC LACE Predictability Area - two main subjects:

- **ALADIN-LAEF**
- **AROME-EPS**

ALADIN-LAEF

Current R&D topics:

- Supersaturation problem in models with SPPT
- IC and model perturbations for new ALADIN-LAEF
- The ALADIN-LAEF scores after fixing QCPL bug in CY40T1
- ALADIN-LAEF operational upgrade

ALADIN-LAEF

Supersaturation problem in models with SPPT:

- SPPT systematically reduces moisture in the model atmosphere
- perturbation of **q** and/or **T** can easily push model into the "supersaturation" state
- due to the irreversible precipitation processes it is cumulatively drying the model atmosphere

ALADIN-LAEF

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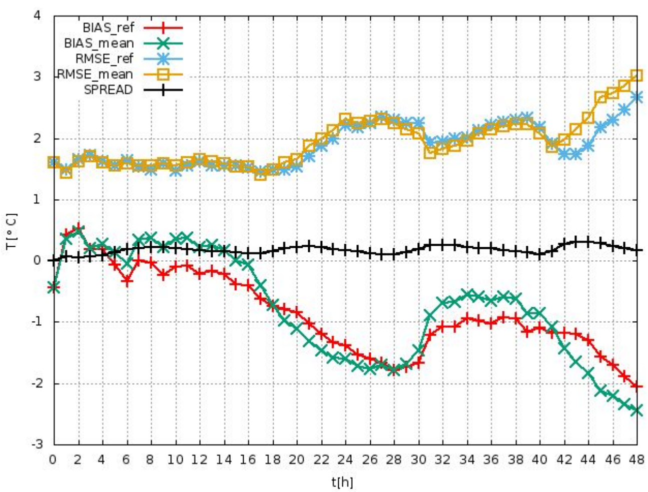
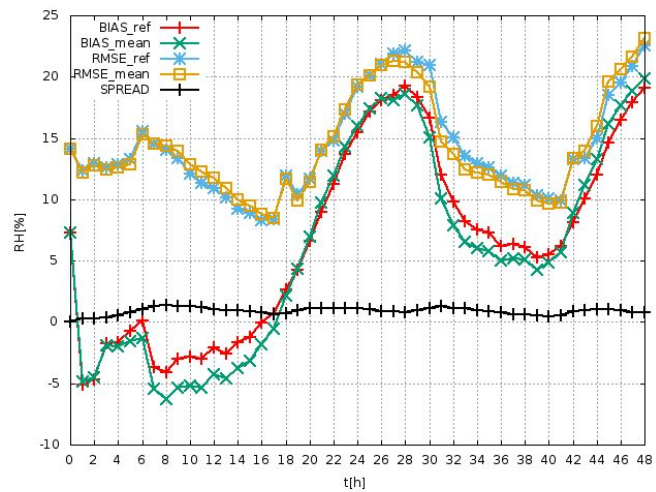
Surface SPPT

Temperature



Relative humidity



ENS mean

deterministic

BIAS and RMSE of temperature (left) and relative humidity (right) for May 15, 2011. BIAS and RMSE of deterministic run are denoted by red and blue lines respectively. BIAS and RMSE of the ensemble mean are denoted by green and yellow lines respectively. Hourly measurements from stations below 600 m a.s.l. were used in this verification.

ALADIN-LAEF

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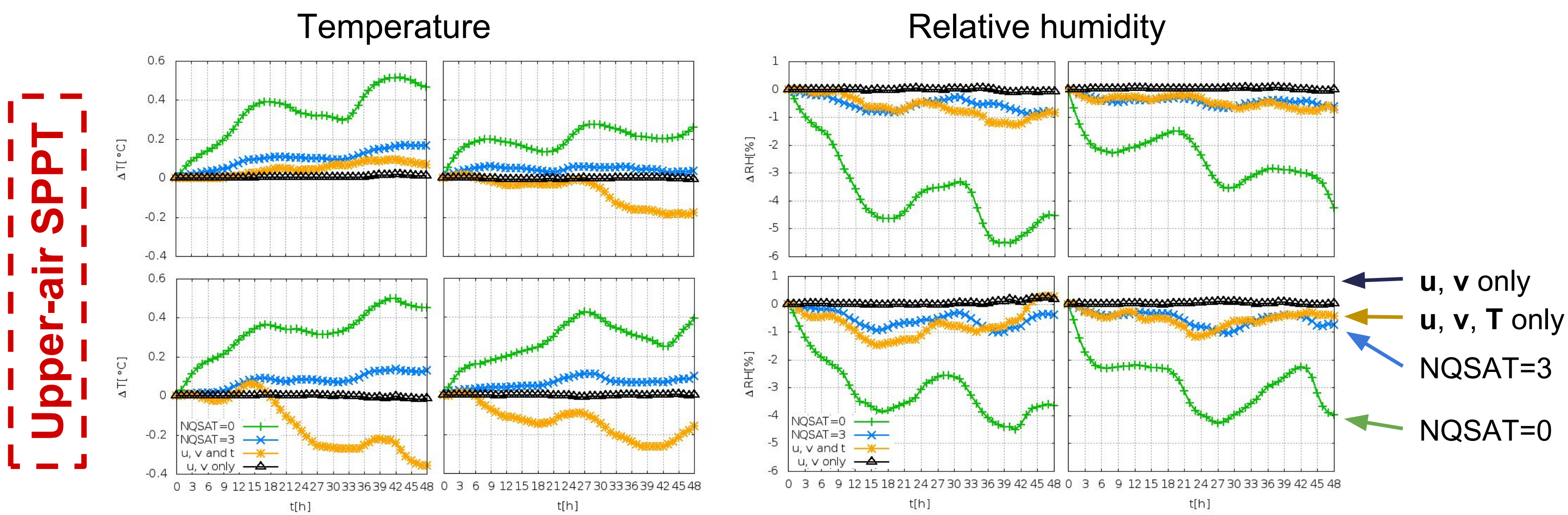

Temperature (left) and relative humidity (right) differences between the experiment with SPPT (8 members) and reference deterministic run at 850 hPa for 4 independent cases averaged over the domain.

ALADIN-LAEF

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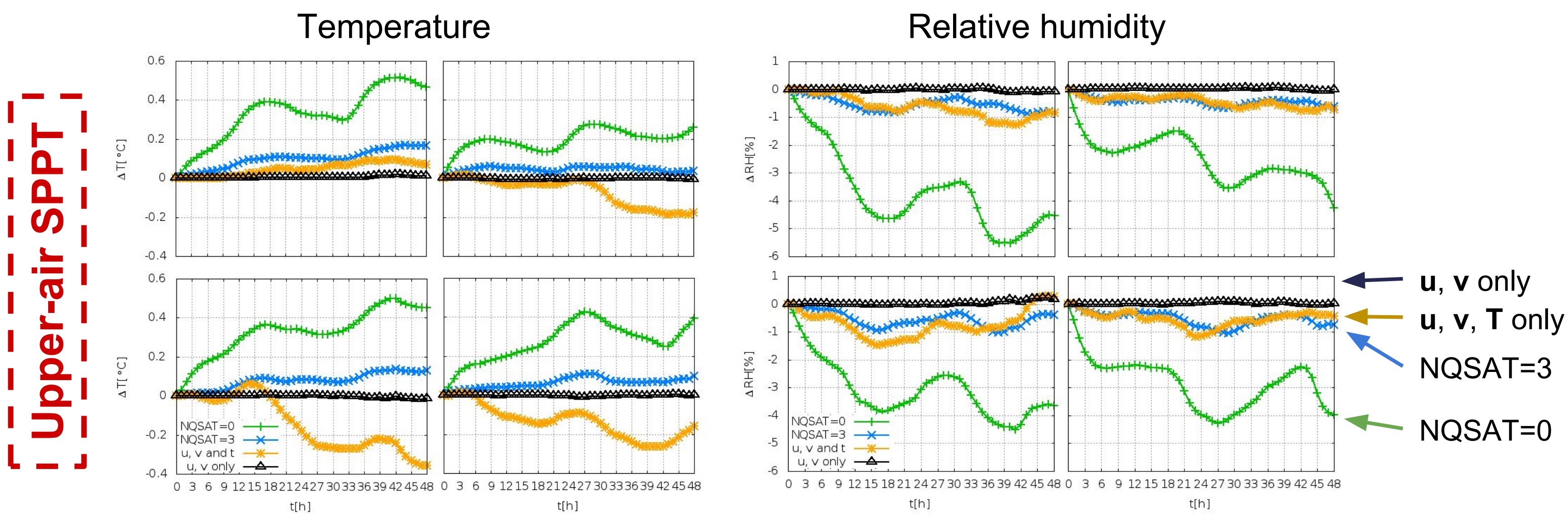
For the upper-air still issue, needs to be investigated further.



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ALADIN-LAEF

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- **Supersaturation problem in models with SPPT**
- **IC and model perturbations for new ALADIN-LAEF**
- **The ALADIN-LAEF scores after fixing QCPL bug in CY40T1**
- **ALADIN-LAEF operational upgrade**

ALADIN-LAEF

IC and model perturbations for new ALADIN-LAEF:

- Ensemble of Surface Data Assimilation (ESDA) was implemented with:
  - external OBS perturbation
  - internal OBS perturbation
- Model perturbation simulated by:
  - stochastic physics (surface SPPT - ISBA prognostic fields)
  - reduced set of different physics parameterizations (ALARO-1)
- The impact of each perturbation method was evaluated
- Remark: coupling issue when GL tool is used

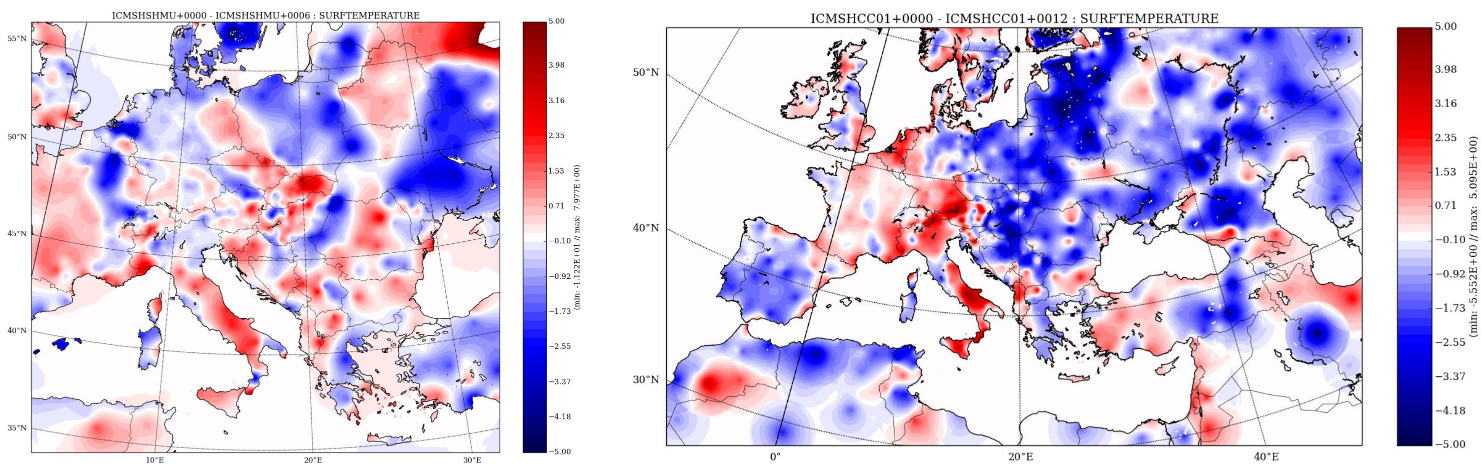
ALADIN-LAEF

IC and model perturbations for new ALADIN-LAEF:

IC perturbation - ESDA:

- OBS perturbation - external program ECMAPERT (by A. Storto) was phased to cy40t1
- OBS perturbation - internal method by configuration screening has been scripted into canari.pl

Assimilation increments



The assimilation increments for surface temperature (analysis - guess) for SHMU oper suite 4.5 km (left) and LAEF 4.8 km (right) - both on the cycle 40t1. The corresponding color scales are equal for direct intercomparison. Note that the analyzed day is different for SHMU and LAEF, and also LAEF assimilation cycle was tested (warmed up) only for one week period.

ALADIN-LAEF

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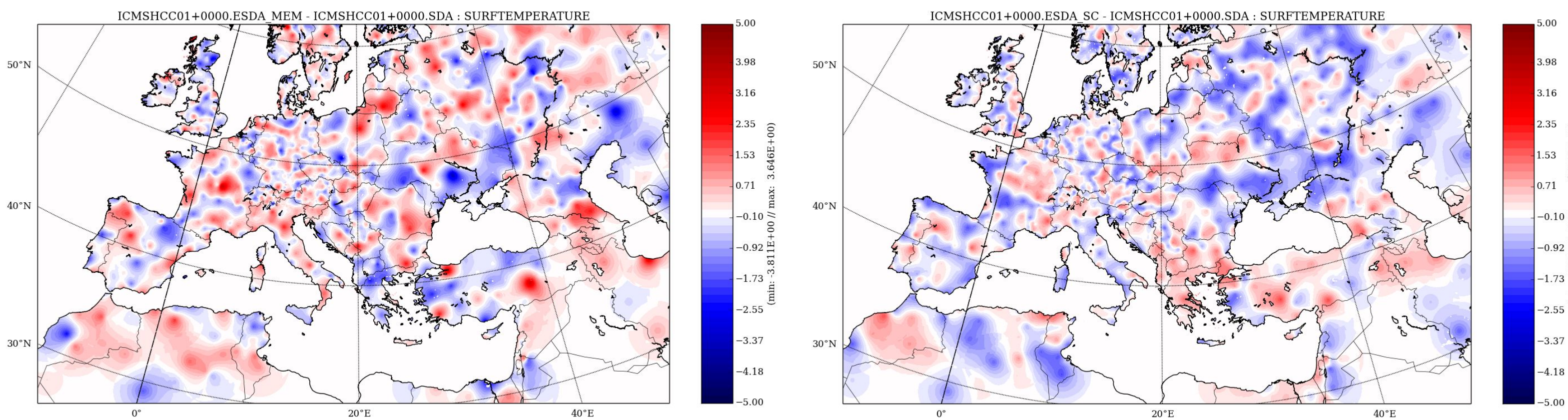
Perturbations



The temperature perturbation at the surface (pertOBS analysis - reference analysis) for LAEF 4.8 km domain on cycle 40t1. There is ensemble member 01 perturbation by external method (left) and by internal method (right) - both initialized with the same SEED number.

ALADIN-LAEF

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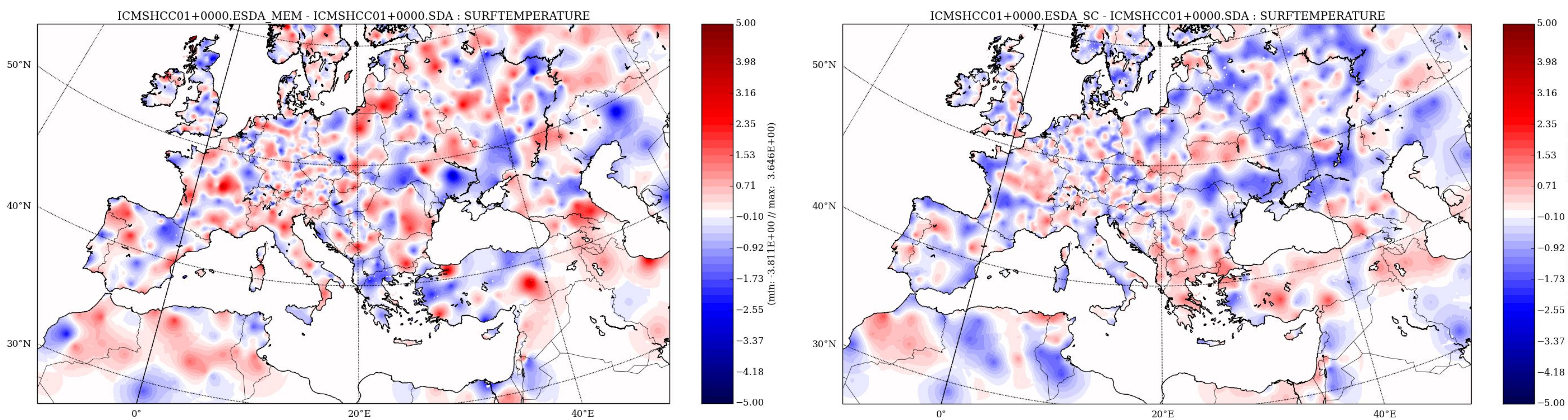
maintenance

reversed order of QC

Perturbations



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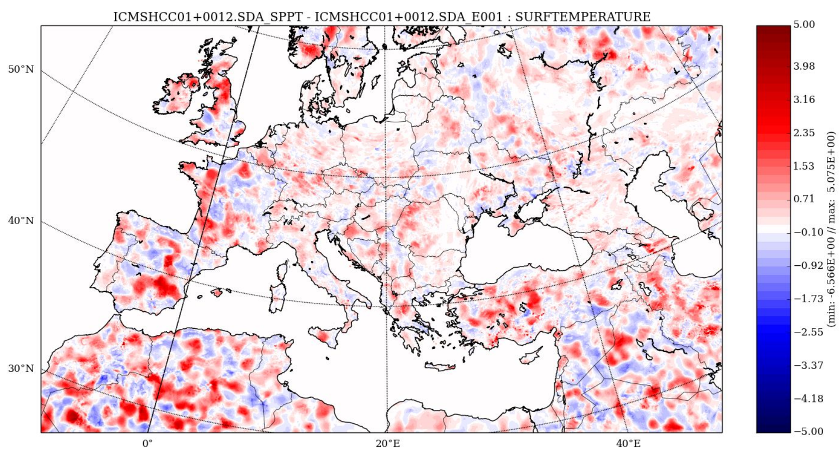
ALADIN-LAEF

IC and model perturbations for new ALADIN-LAEF:

Model perturbation:

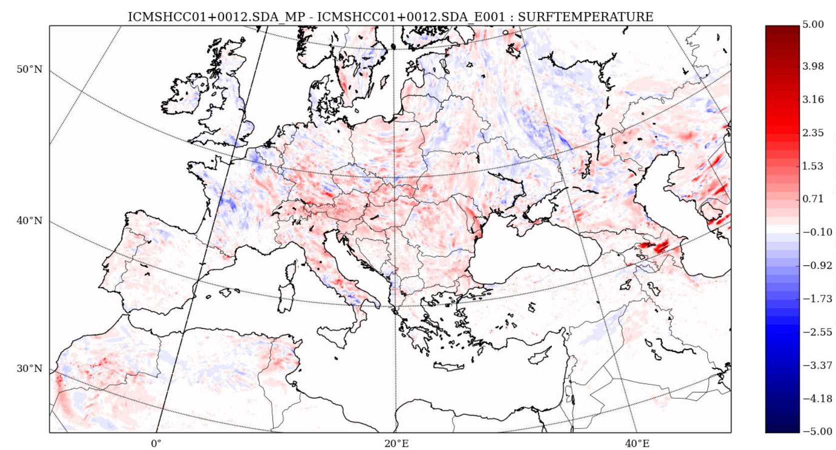
- SPPT - perturbation is called each time step in grid-point space for ISBA prognostic fields (except deep soil)
- Multiphysics - reduced set of ALARO-1 namelists with tuned microphysics, turbulence and deep convection

SPPT



Configuration 1

MP



Surface temperature perturbation due to SPPT after 12h of integration (left) and due to MP for 3 different namelist configurations (right). The fourth namelist configuration is default ALARO-1 physics.

ALADIN-LAEF

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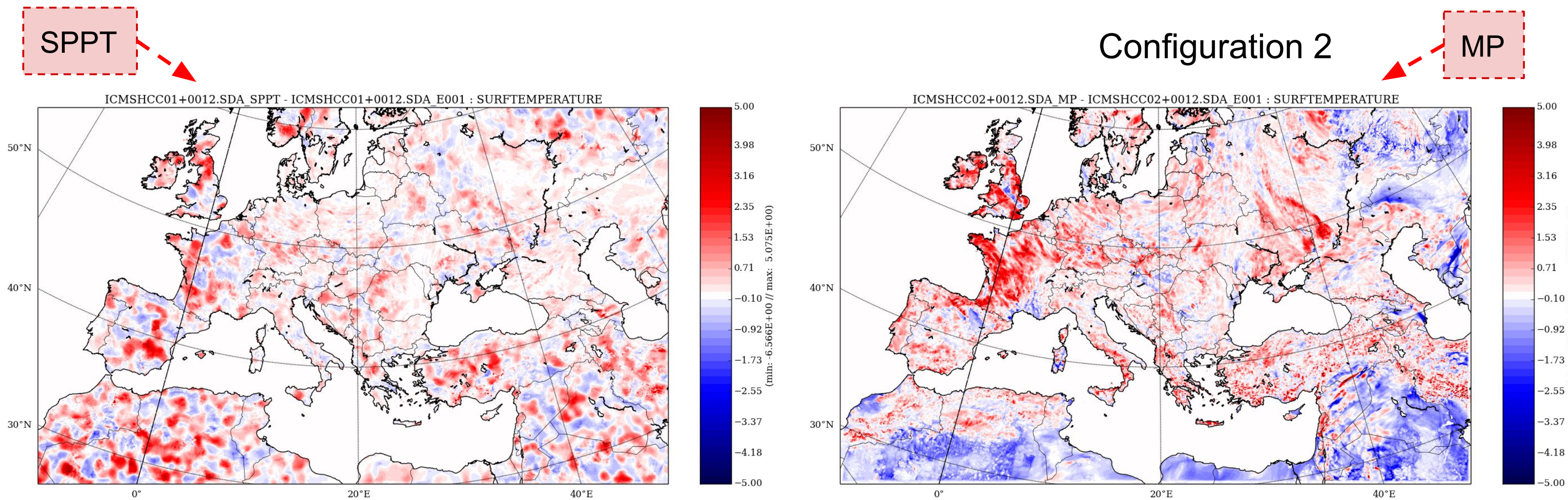

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ALADIN-LAEF

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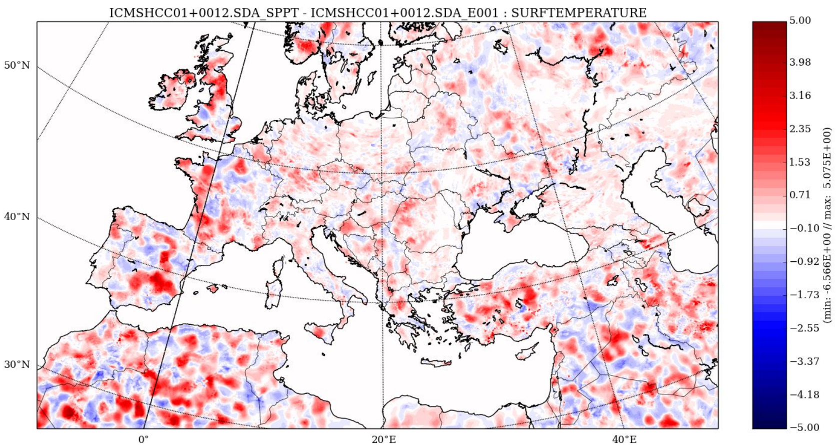
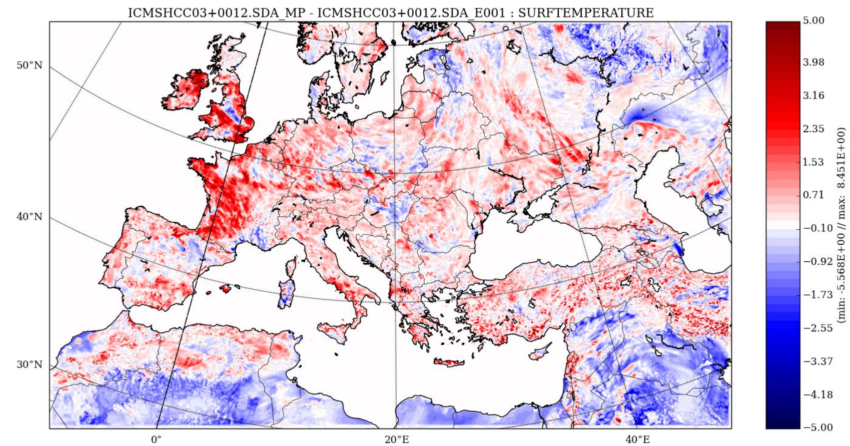
SPPT

Configuration 3

MP





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ALADIN-LAEF

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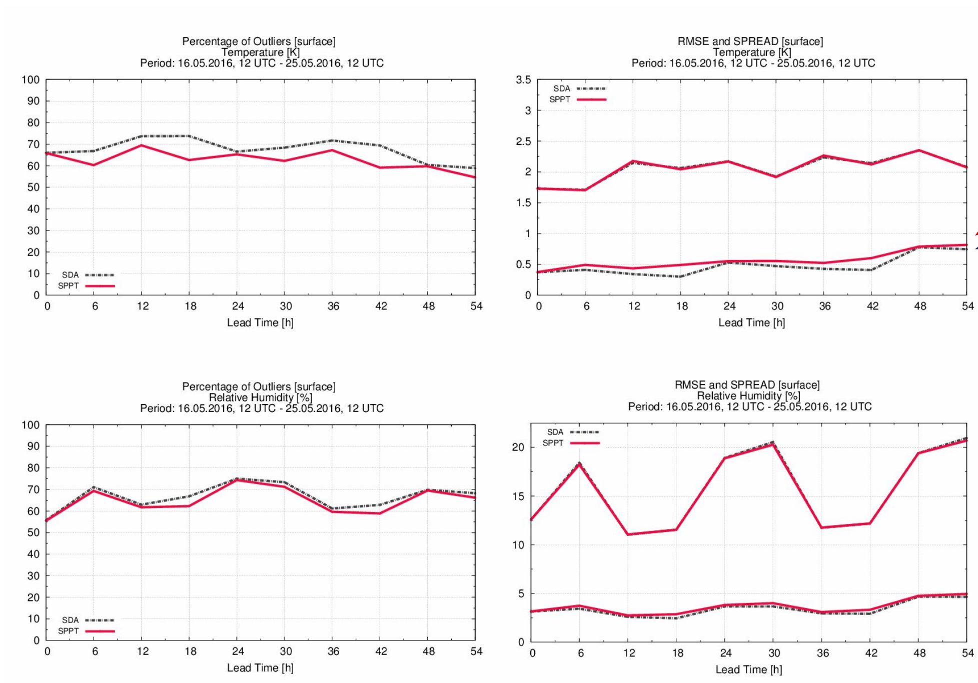
Stochastic perturbation



SPPT (exp)

SDA (ref)

Temperature (up) and relative humidity (bottom) verification for the period of 10 days from 16 to 25 May 2016, 12 UTC run of the full LAEF ensemble (16 members). The percentage of outliers (left) and RMSE of the ensemble mean with ensemble spread (right) are shown for the reference (SDA, black dashed) and stochastically perturbed physics tendencies of surface prognostic fields experiment (SPPT, red).

ALADIN-LAEF

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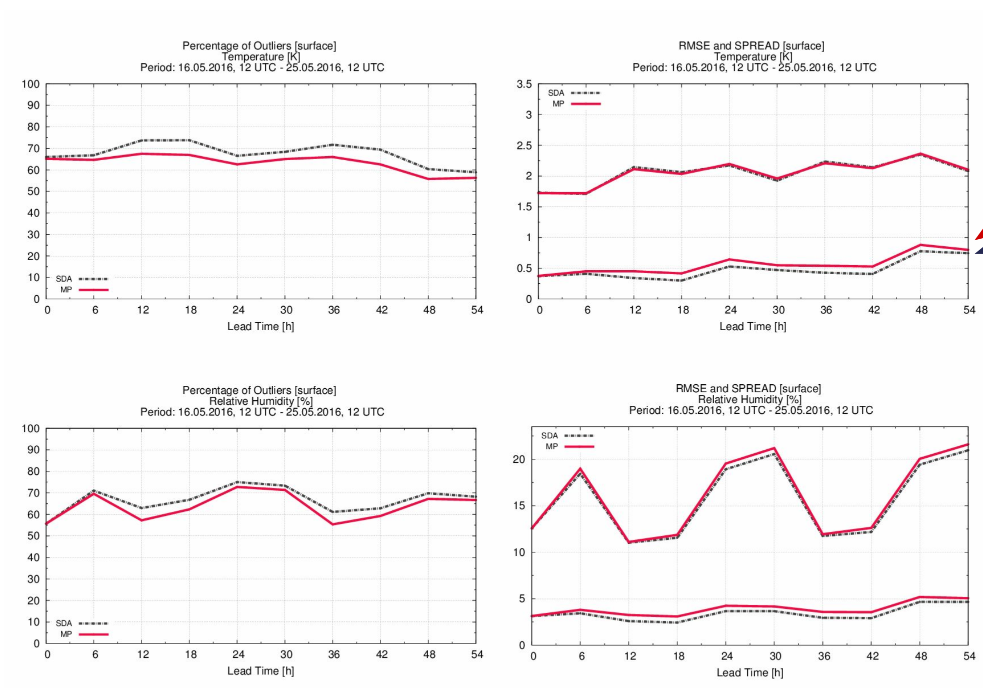
Multiphysics



MP (exp)

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Temperature (up) and relative humidity (bottom) verification for the period of 10 days from 16 to 25 May 2016, 12 UTC run of the full LAEF ensemble (16 members). The percentage of outliers (left) and RMSE of the ensemble mean with ensemble spread (right) are shown for the reference (SDA, black dashed) and multiphysics experiment (MP, red).

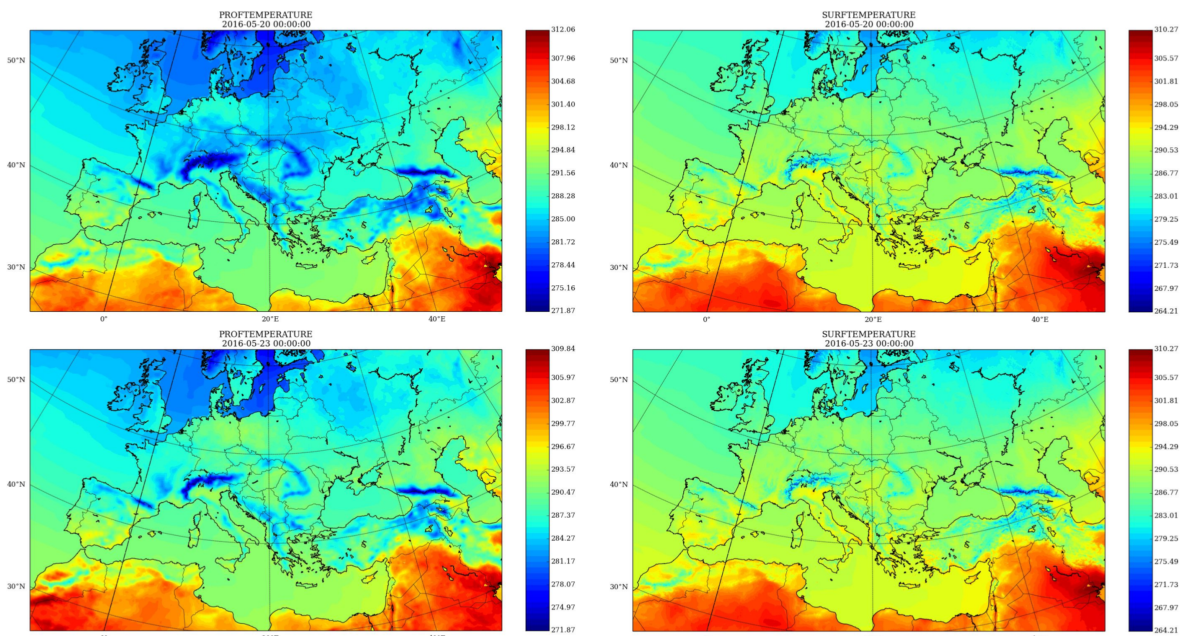
ALADIN-LAEF

IC and model perturbations for new ALADIN-LAEF:

Coupling issue when GL tool is used:

- formerly used configuration 901 can not be applied now to convert the IFS gribs to ALADIN FA files
- GL tool has limitations considering the vertical interpolations (combination with ee927 can be used)
- SFC temperature (sea + land) extracted from CLIM files instead of skin and SST fields (assim cycle can be used)
- inappropriate initial land-surface and sea-surface temperatures (DADA)

Soil temperature | Surface temperature



Run 20 May 2016 00 UTC

3 days

Run 23 May 2016 00 UTC

Constant sea and land surface temperatures (IC).

ALADIN-LAEF

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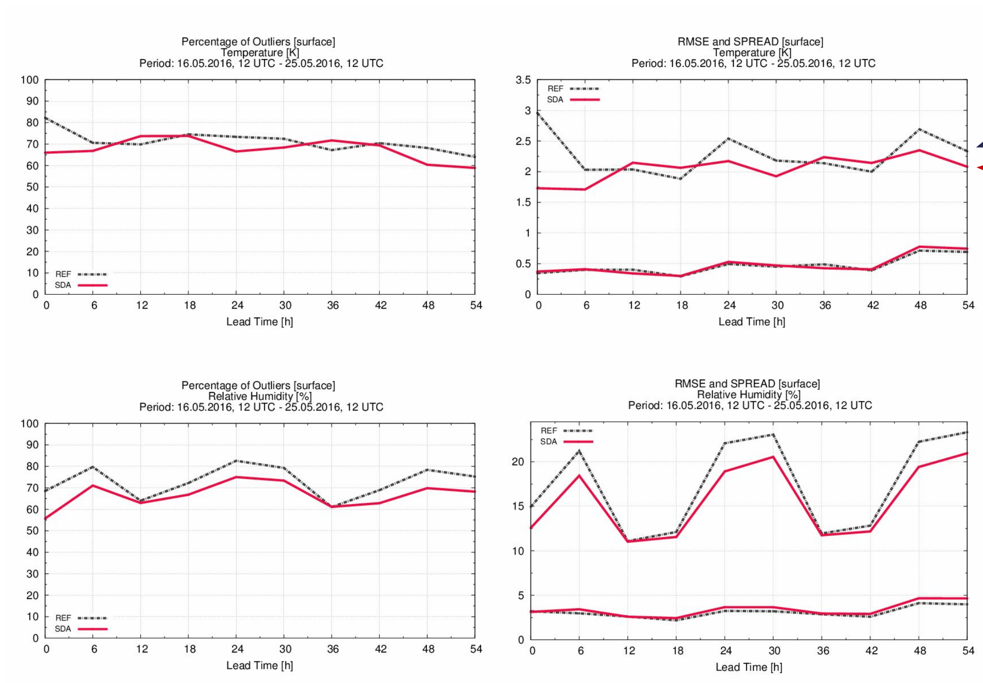

downscaled LBCs (ref)

SDA (exp)

Temperature (up) and relative humidity (bottom) verification scores for the period of 10 days from 16 to 25 May 2016, 12 UTC run of the full LAEF ensemble (16 members). The percentage of outliers (left) and RMSE of the ensemble mean with ensemble spread (right) are shown for the reference (downscaled ECMWF LBCs, black dashed) and surface data assimilation experiment (SDA, red).

ALADIN-LAEF

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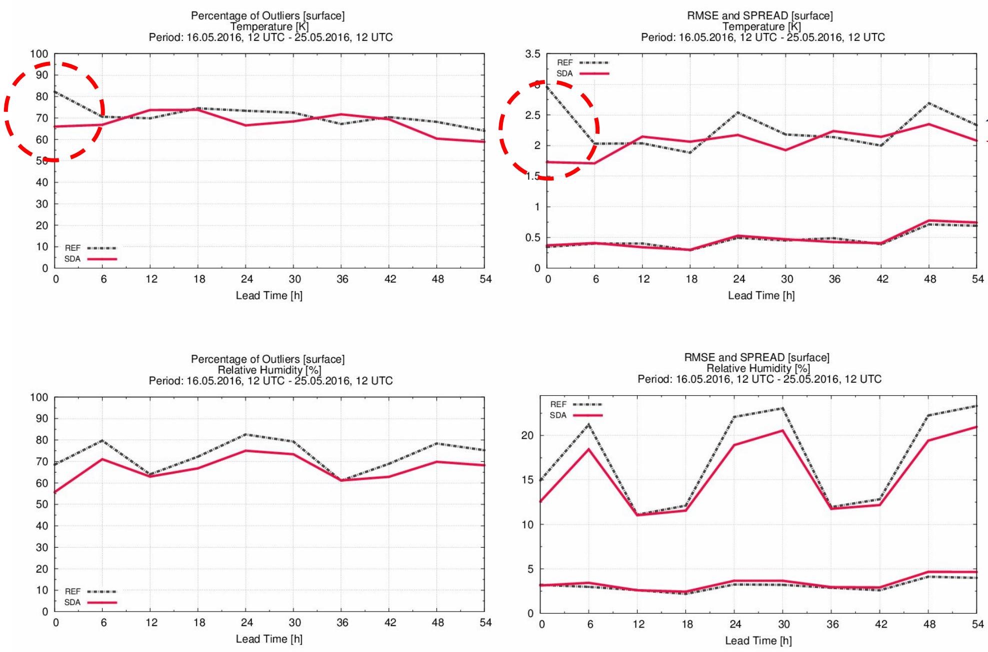

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ALADIN-LAEF

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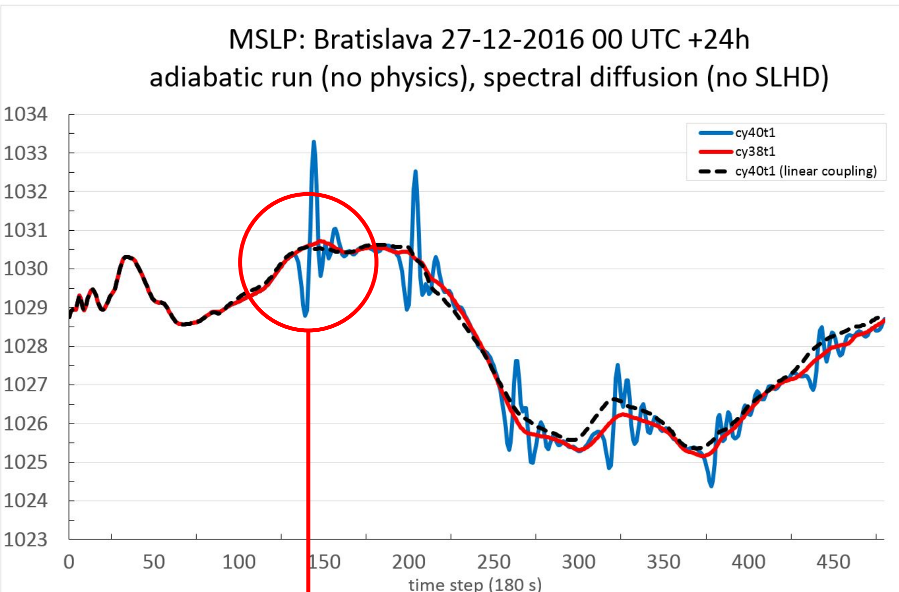
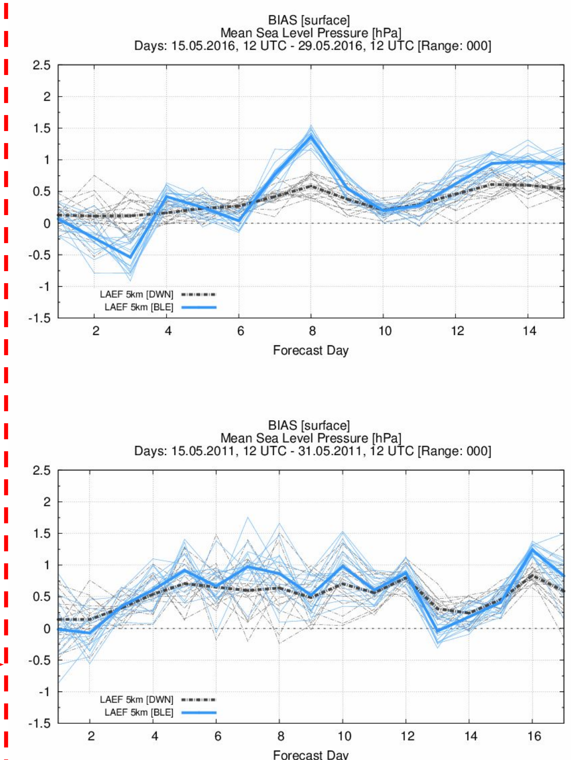
ALADIN-LAEF

Bug in quadratic coupling in CY40T1 (and above cycles):

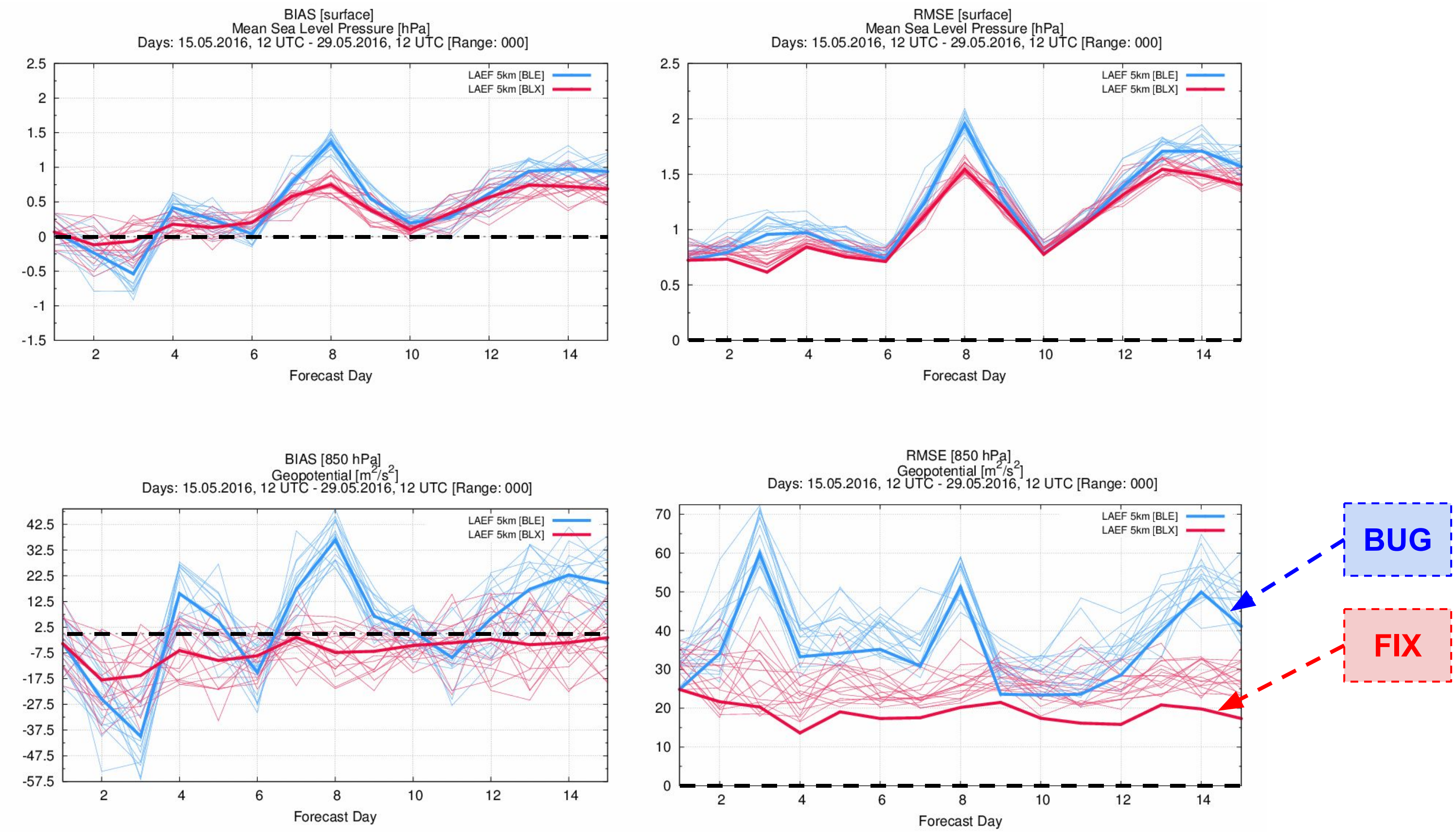


The first guess for blending!



ALADIN-LAEF

The ALADIN-LAEF scores after fixing QCPL bug in CY40T1:



BIAS (left) and RMSE (right) for the initial time along all the experiment days for MSLP (top) and geopotential at 850 hPa (bottom). Blue line represents the blending cycle with bugged QCPL, while the red line is the same after the correction.

ALADIN-LAEF

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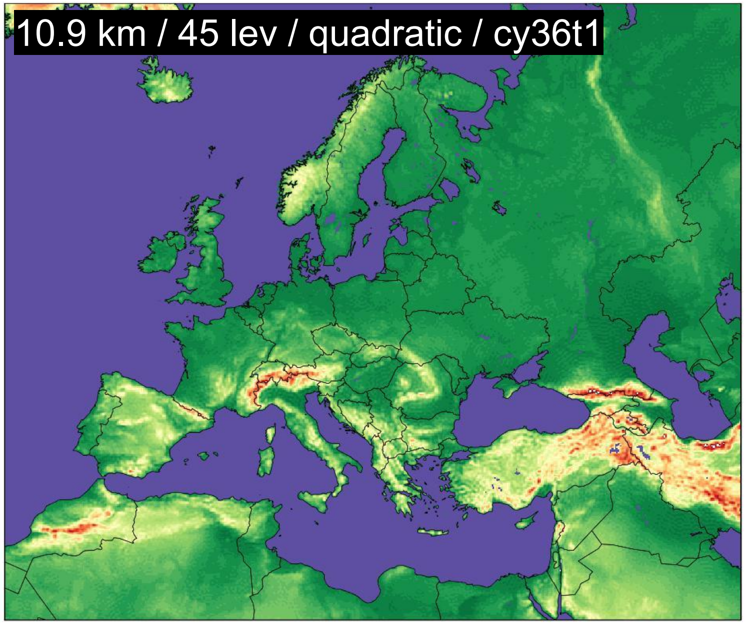
ALADIN-LAEF

ALADIN-LAEF operational upgrade:



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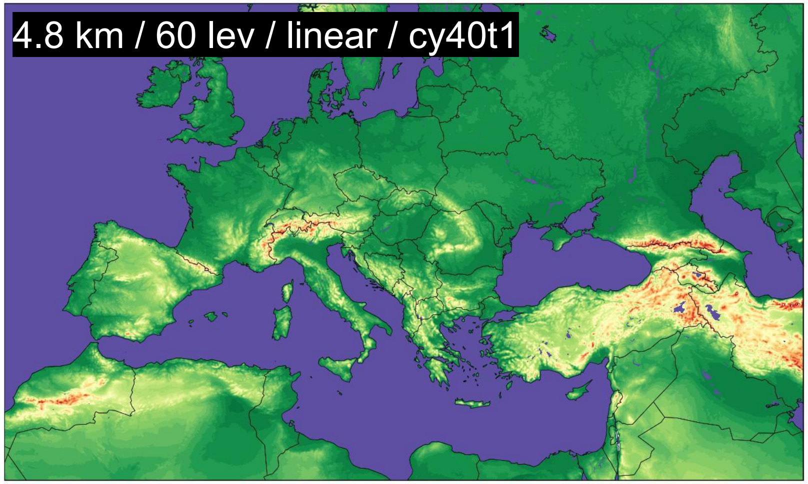


end of 2017

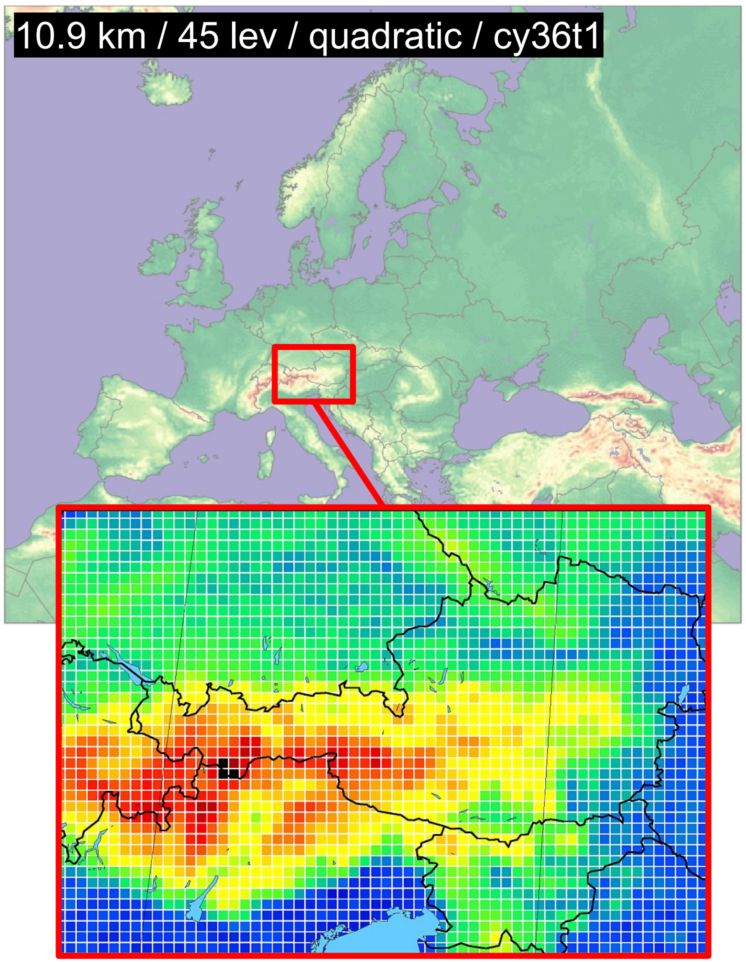
Upgrade in two steps:

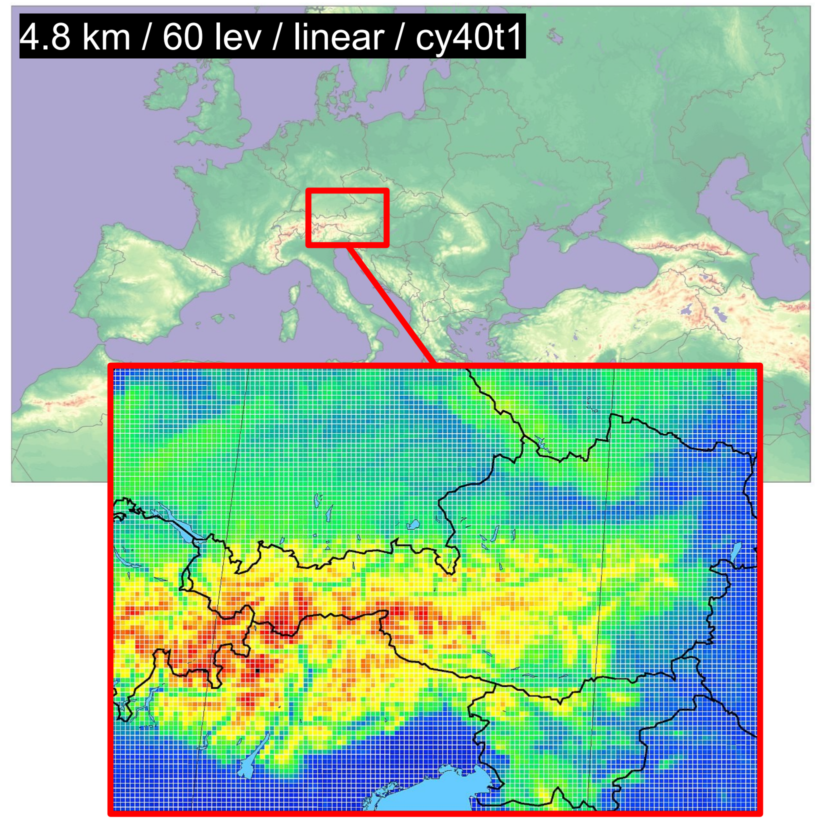
ALADIN-LAEF 5 km / 60 lev
@CY40T1

- phase I: ESDA+Blend (IC); SPPT+ALARO-1 MP (model)
- phase II: ENS BlendVar (instead of BB)

ALADIN-LAEF

ALADIN-LAEF operational upgrade:





AROME-EPS

Current R&D topics:

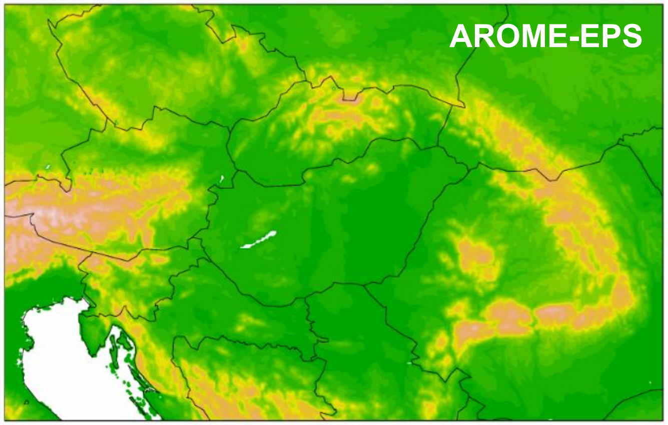
- Development at OMSZ related to ensemble systems
- Implementation of Stochastic Pattern Generator (SPG) in ALADIN code
- AROME-EPS experiments at ZAMG
- Jk 3DVar method (Endi's PhD)

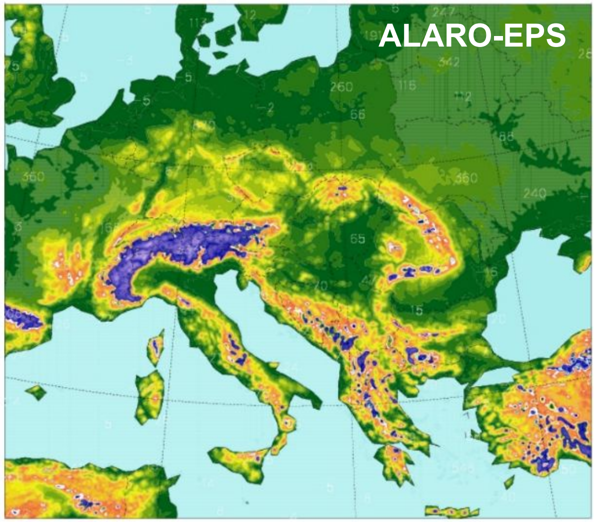
AROME-EPS

Developments at OMSZ related to ensemble systems:

Ensembles running by OMSZ:

- AROME-EPS
  - test version
  - running at ECMWF on cca ('SPFRBOUT' special project)
  - ensemble members: 11
  - forecast length: +36 h (starting from 18 UTC only)
  - coupling: PEARP (Meteo-France)
- ALARO-EPS
  - operational version
  - running at OMSZ
  - horizontal resolution: 8 km
  - ensemble members: 11
  - forecast length: +60 h (starting from 18 UTC only)
  - coupling: ECMWF-EPS (since October 2016)





Supersaturation check in SPPT (drying effect):

- different NQSAT settings
- iteratively decreased perturbations
- decreased standard deviation (smaller perturbations)

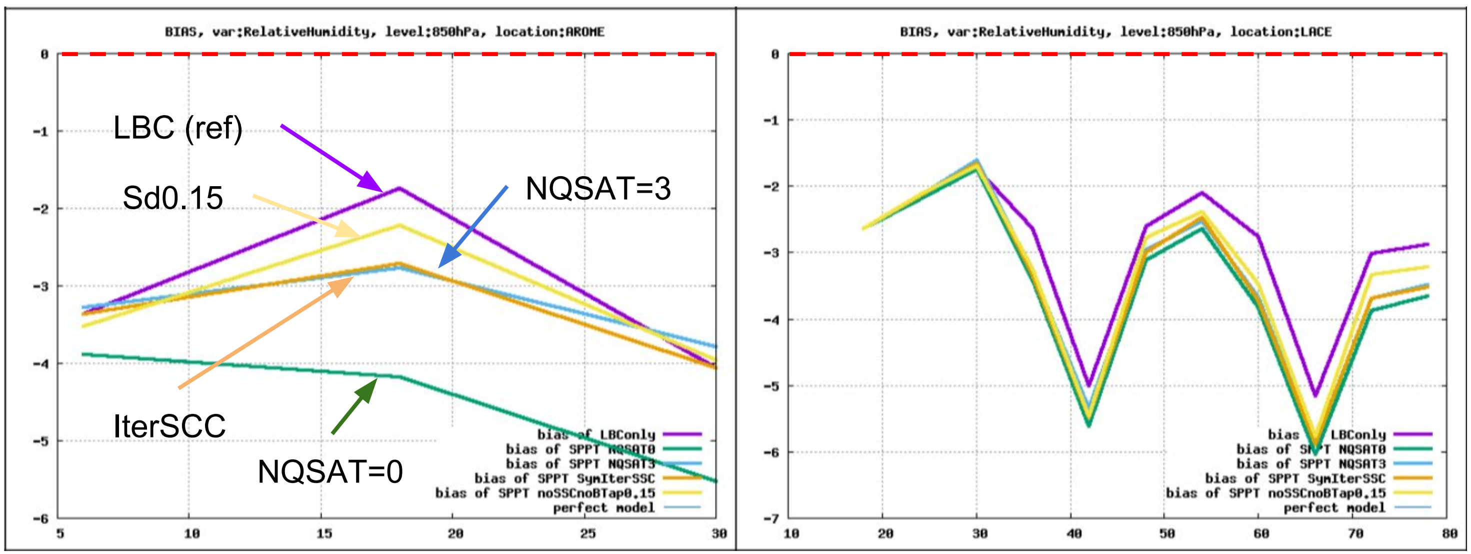
New SPG implementation (2D random patterns, cy38)

AROME-EPS

Developments at OMSZ related to ensemble systems:

Supersaturation check (SSC) in SPPT:

- the comparison of four possible handling of the SSC problem
- NQSAT=0, NQSAT=3, iterative approach, no SSC (nor tapering) but much smaller sigma



Relative humidity BIAS at 850 hPa level for different supersaturation adjustment experiments - AROME-EPS (left), ALARO-EPS (right).

AROME-EPS

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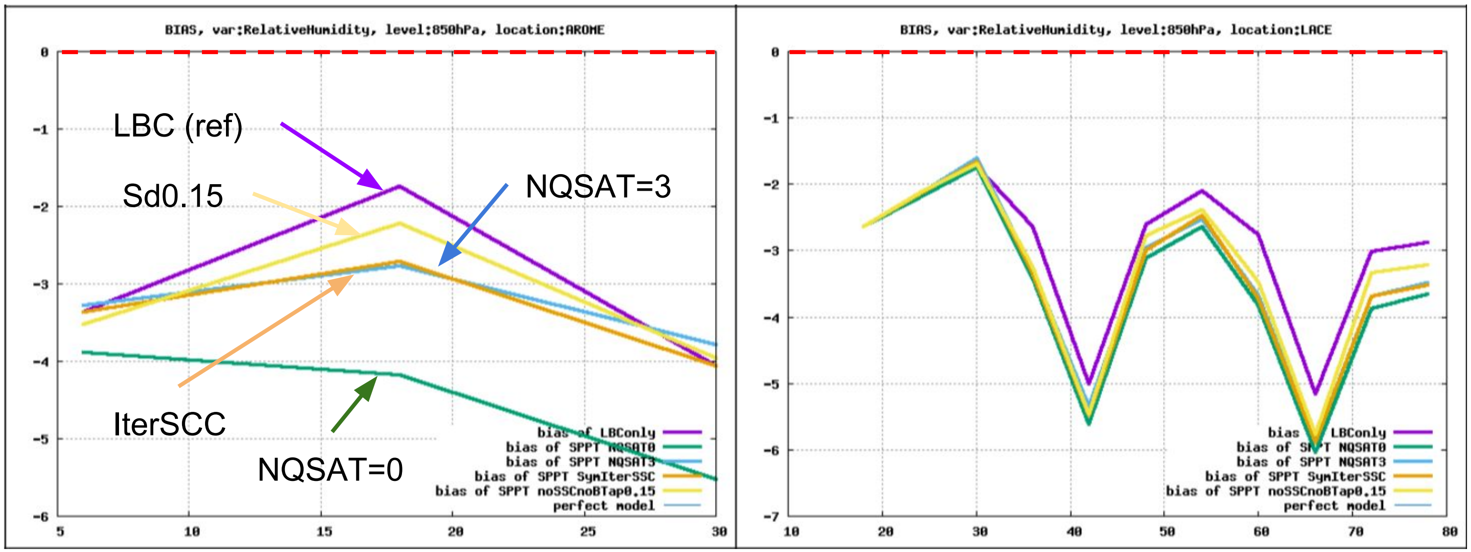
Q: Special LAM-fitted SSC or smaller perturbations without artificial filtering like SSC or tapering?



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AROME-EPS

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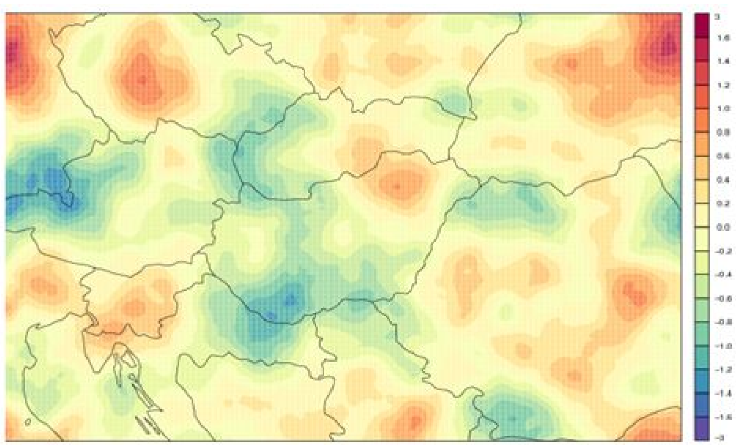
- **AROME-EPS experiments at ZAMG**
- **Jk 3DVar method (Endi's PhD)**

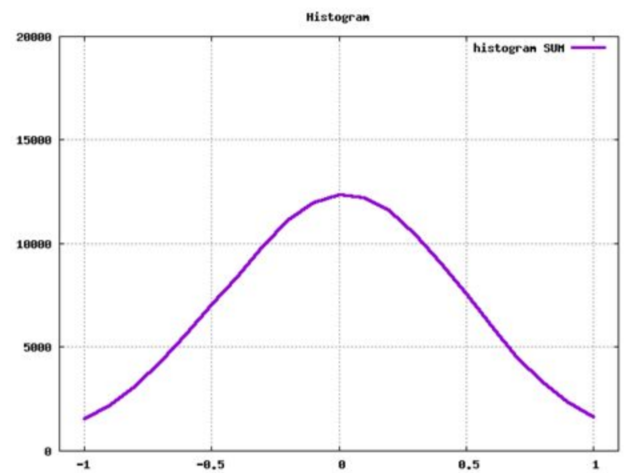
AROME-EPS

Implementation of Stochastic Pattern Generator (SPG) in ALADIN code:

Properties:

- model errors are represented at various scales
- larger (shorter) spatial scales are associated with larger (shorter) temporal scales
- pattern features are correctly tunable by the namelist values
- generation of Gaussian noise and Fast Fourier Transform (FFT) available in ALADIN code
- well-described theoretical background of SPG scheme (by Tsyrulnikov and Gayfulin, 2016)





Random field generated by SPG (in ALADIN code implementation) for Hungarian AROME domain (left) and the statistical distribution of random numbers (right).

AROME-EPS

Implementation of Stochastic Pattern Generator (SPG) in ALADIN code:

BEFORE

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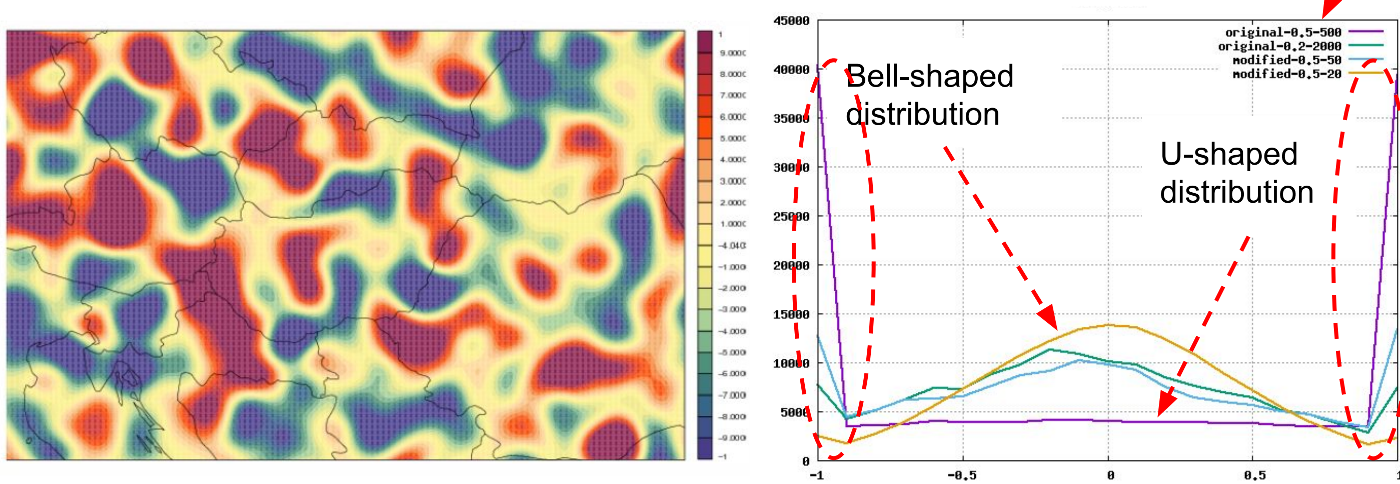
Statistical distribution of random numbers within old SPPT scheme.



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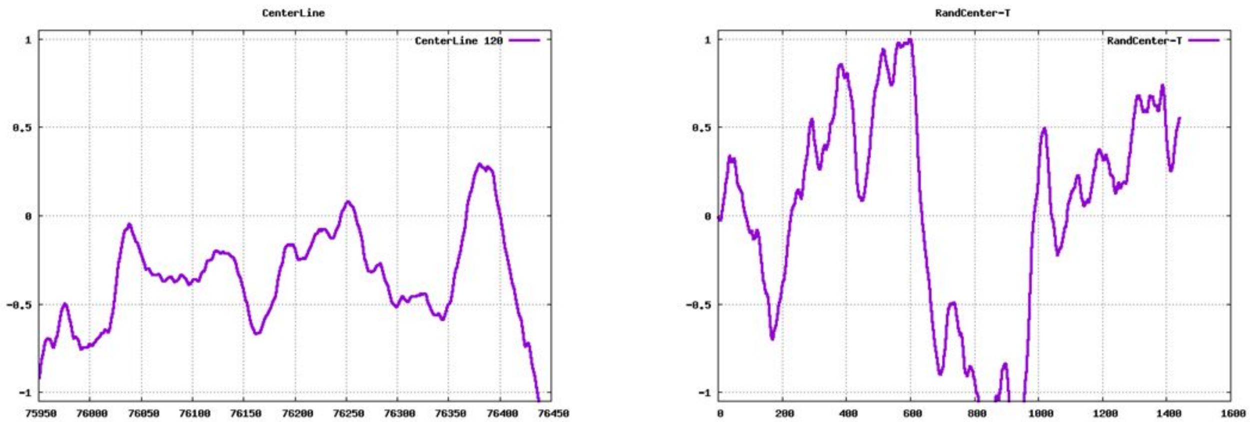
AROME-EPS

Implementation of Stochastic Pattern Generator (SPG) in ALADIN code:

Benefits:

- new SPG can be used for partial or total tendencies perturbation
- model uncertainty representation by the random patterns (also in the future)
- SPG can be very useful also from the surface perturbation aspects



An x-oriented cross-section of the random pattern generated by SPG in ALADIN code implementation (left) and the time evolution of the random value of a given gridpoint in the center of the domain (right).

AROME-EPS

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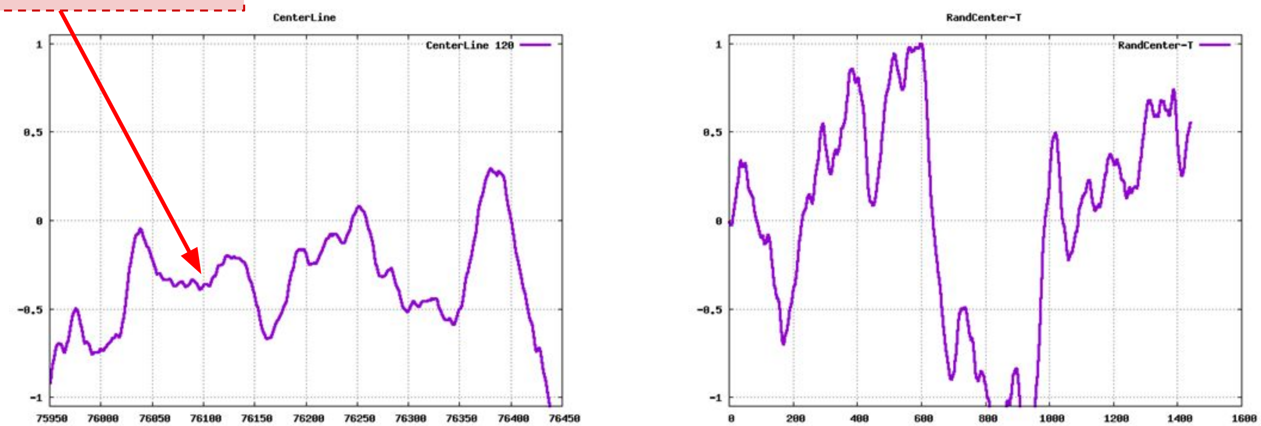
Small scale structures.



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AROME-EPS

AROME-EPS experiments at ZAMG:

Computing resources for an operational setting of AROME-EPS are not sufficient. Procurement of a new HPC is ongoing and the machine should be delivered this October. For now, only non-operational AROME-EPS experiments were done at ZAMG and at the ECMWF HPCF with the following configuration:

- AROME-EPS
  - test version
  - domain size: 492 x 594 grid points
  - horizontal resolution: 2.5 km
  - vertical levels: 90
  - time step: 60s
  - ensemble members: 16
  - forecast length: +36h
  - initialization: ECMWF downscaling
  - coupling: ECMWF-EPS (time-lagged 6h)
  - coupling frequency: 3h

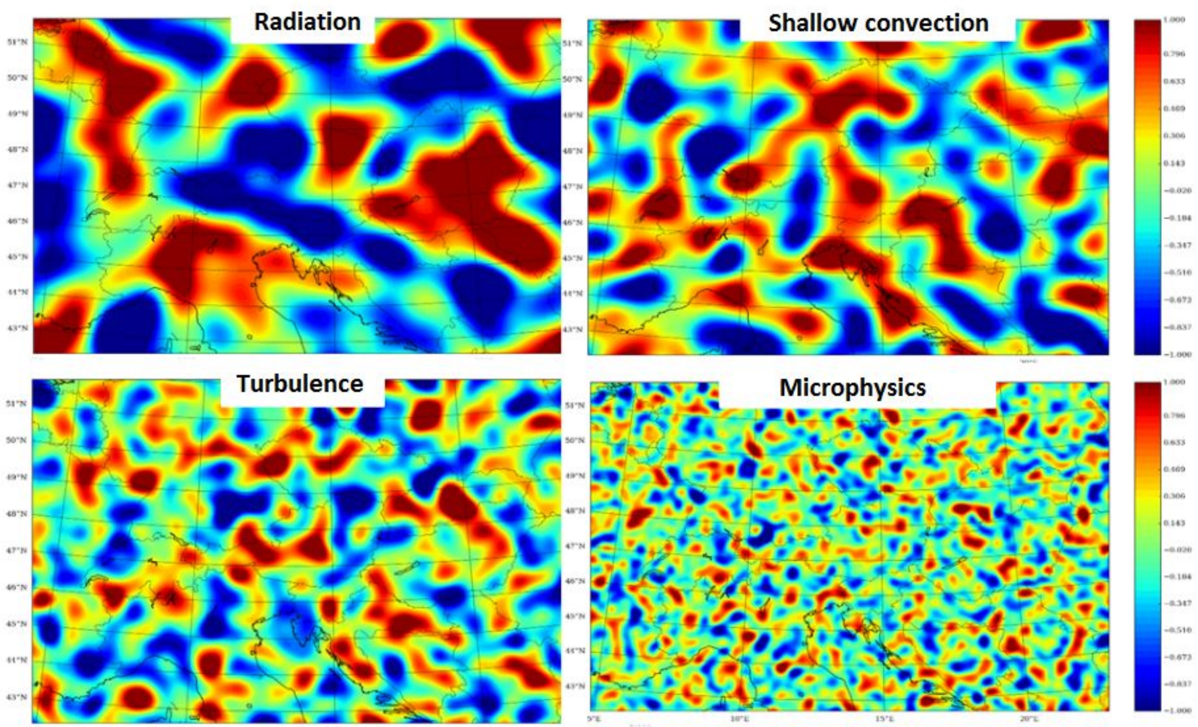
- AROME-EPS (ZAMG)
  - pre-operational version (planned for 2018)

AROME-EPS

AROME-EPS experiments at ZAMG:

Partial model tendencies perturbation (upgrade):

- tendencies (T, q, u, v) of radiation, turbulence, shallow convection and microphysics are perturbed separately
- separate random patterns are used
- except the RND seed also horizontal and temporal scale is adapted for the different parameterizations



Different perturbation patterns with adapted scales for given physics schemes in AROME.

AROME-EPS

AROME-EPS experiments at ZAMG:

Partial model tendencies perturbation (upgrade):

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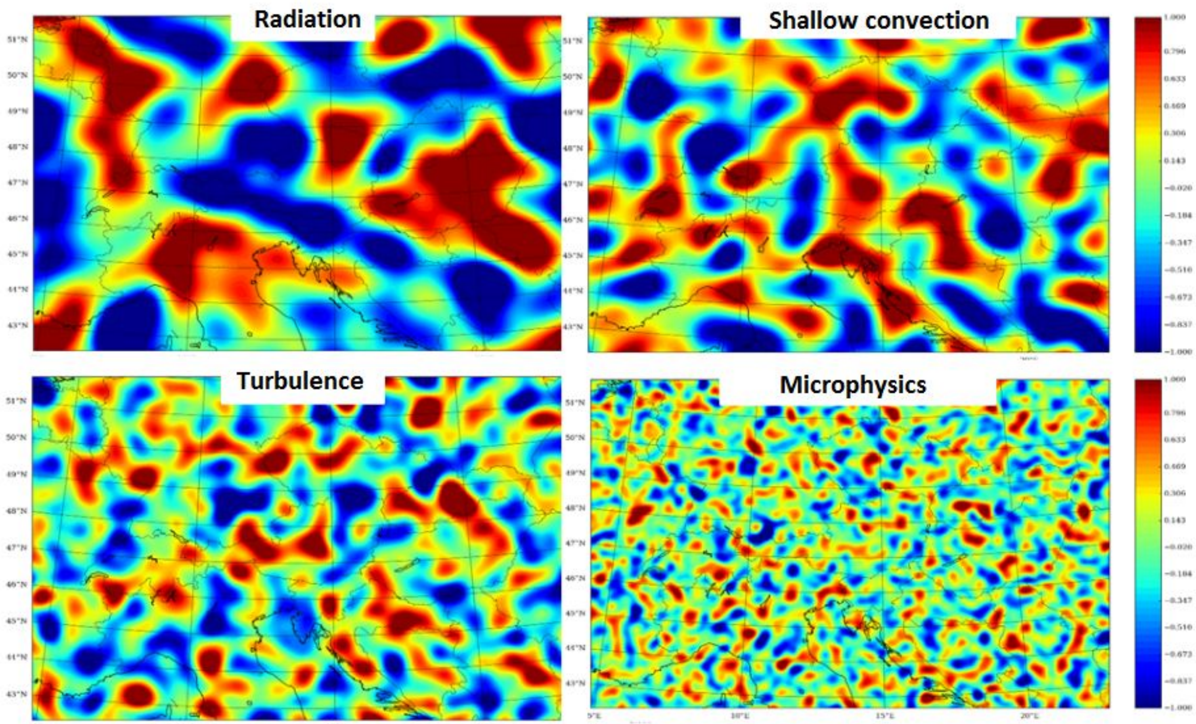

For microphysics the uncertainties are naturally on a very small scale.

Different perturbation patterns with adapted scales for given physics schemes in AROME.

AROME-EPS

AROME-EPS experiments at ZAMG:

Partial model tendencies perturbation (upgrade):

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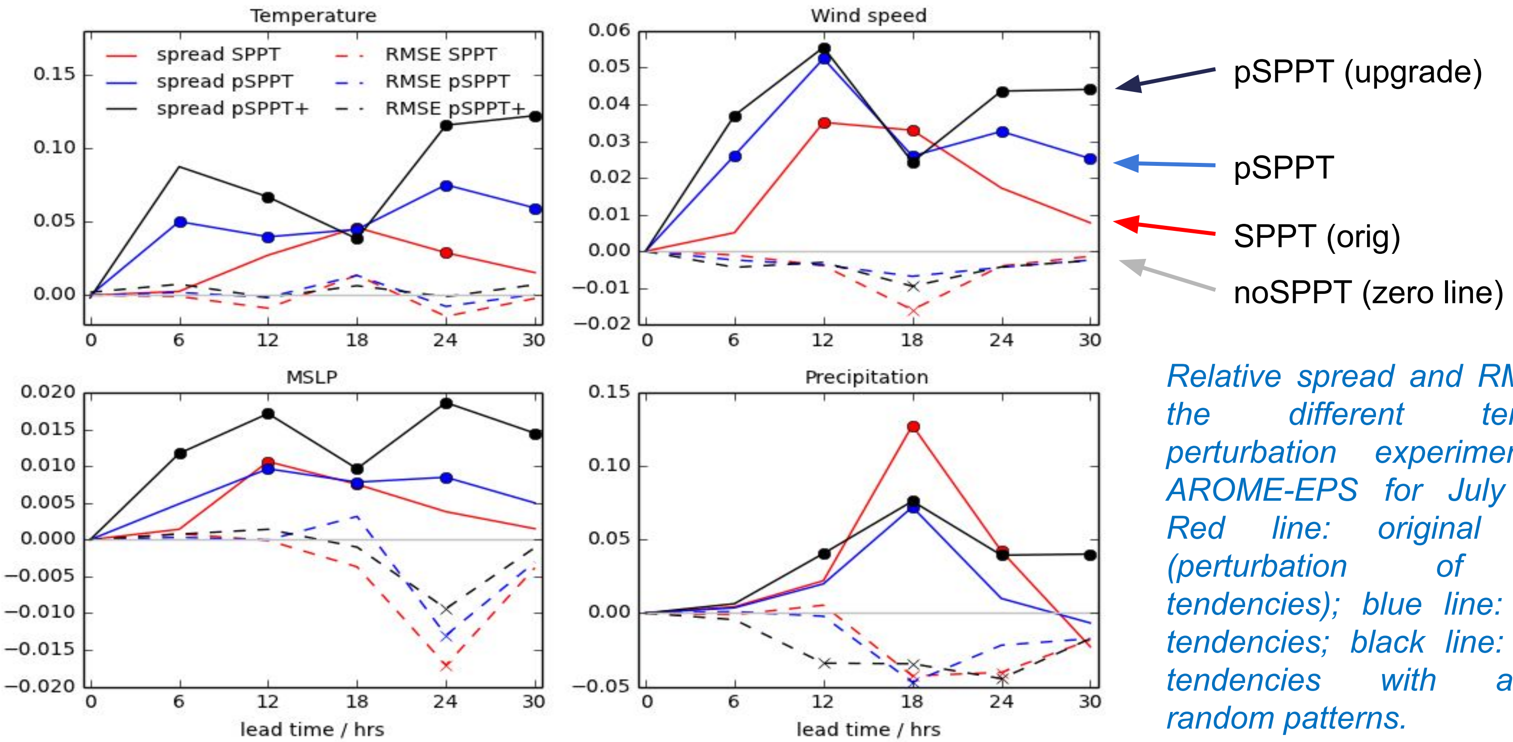

Relative spread and RMSE of the different tendency perturbation experiments in AROME-EPS for July 2016. Red line: original SPPT (perturbation of total tendencies); blue line: partial tendencies; black line: partial tendencies with adapted random patterns.

AROME-EPS

Current R&D topics:

- Development at OMSZ related to ensemble systems
- Implementation of Stochastic Pattern Generator (SPG) in ALADIN code
- AROME-EPS experiments at ZAMG
- Jk 3DVar method (Endi's PhD)

AROME-EPS

Jk 3DVar method (Endi's PhD):

- general idea like spectral blending but technically different
- include global model information directly into LAM variational assimilation
- combination of large scale (GM-EPS) and small scale (LAM-EPS) perturbations
- consistent IC and LBC perturbations in convection-permitting EPS

Cost function (3DVar):

$$J(x) = \underbrace{\frac{1}{2}(x - x_b)^T B^{-1}(x - x_b)}_{J_b} + \underbrace{\frac{1}{2}(y - Hx)^T R^{-1}(y - Hx)}_{J_o}$$

Cost function in Jk blending method:

$$J(x) = J_b + J_o + \underbrace{\frac{1}{2}(x - x_{ls})^T V^{-1}(x - x_{ls})}_{J_k} = J_b + J_o + J_k$$

AROME-EPS

Jk 3DVar method (Endi's PhD):

- general idea like spectral blending but technically different
- include global model information directly into LAM variational assimilation
- combination of large scale (GM-EPS) and small scale (LAM-EPS) perturbations
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16 ECMWF EPS members interpolated into AROME 2.5 km domain, 2 weeks in Jan, Apr, Jul, Oct (annual variability), 896 differences used.

Cost function (3DVar):

$$J(x) = \underbrace{\frac{1}{2}(x - x_b)^T B^{-1}(x - x_b)}_{J_b} + \underbrace{\frac{1}{2}(y - Hx)^T R^{-1}(y - Hx)}_{J_o}$$

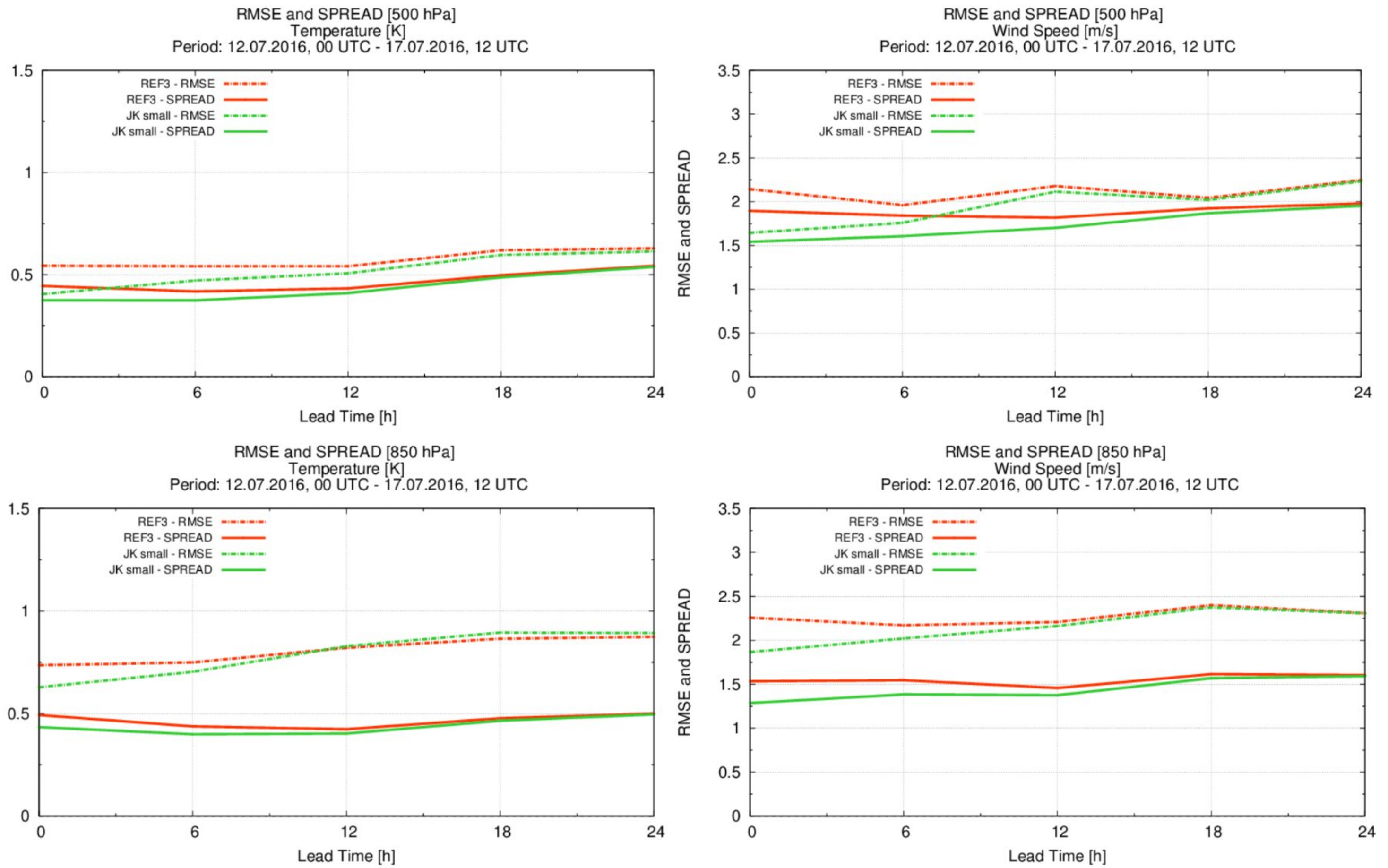
Cost function in Jk blending method:

$$J(x) = J_b + J_o + \underbrace{\frac{1}{2}(x - x_{ls})^T V^{-1}(x - x_{ls})}_{J_k} = J_b + J_o + J_k$$

Large scale perturbations.

AROME-EPS

Jk 3DVar method (Endi's PhD):

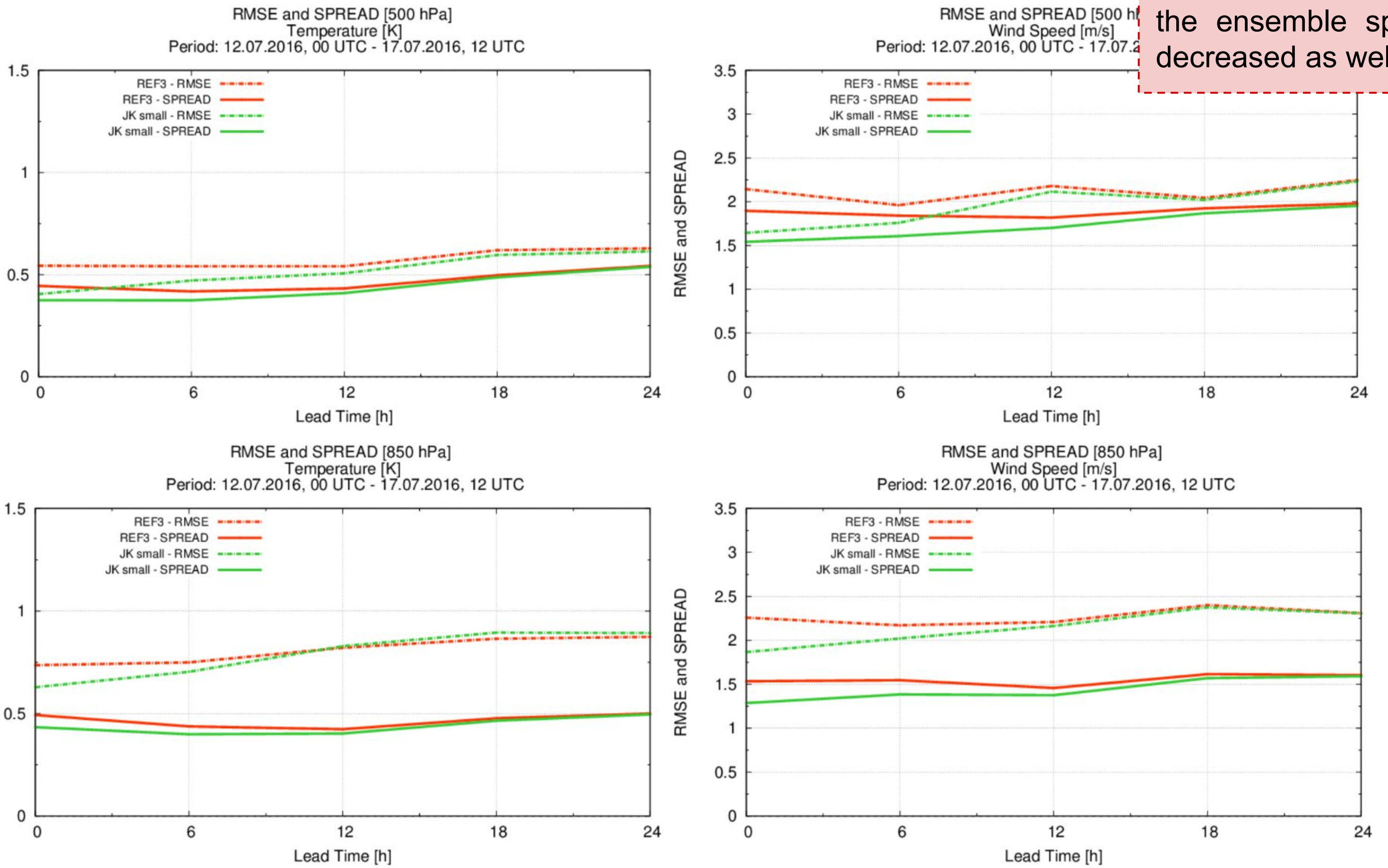


RMSE and SPREAD at 500 hPa (top) and 850 hPa (bottom) for temperature (left) and wind speed (right). The Jk experiment is green and the reference is red (AROME-EPS with 3DVar without Jk term).

AROME-EPS

Jk 3DVar method (Endi's PhD):

Reduced RMSE for the upper air variables at least for the first 12h, however the ensemble spread was decreased as well.



RMSE and SPREAD at 500 hPa (top) and 850 hPa (bottom) for temperature (left) and wind speed (right).
The Jk experiment is green and the reference is red (AROME-EPS with 3DVar without Jk term).

Publications

Submitted papers (2017):

- Wang Y., M. Belluš, A. Ehrlich, M. Mile, N. Pristov, P. Smolíková, O. Španiel, A. Trojáková, R. Brožková, J. Cedilnik, D. Klarić, T. Kovačić, J. Mašek, F. Meier, B. Szintai, S. Tascu, J. Vivoda, C. Wastl, Ch. Wittmann, 2017: "***26 years of Regional Co-operation for Limited Area Modelling in Central Europe (RC LACE)***", submitted to BAMS on July 26, 2017 (currently in review)
- Ihász I., A. Mátrai, B. Szintai, M. Szűcs, I. Bonta, 2017: "***Application of European numerical weather prediction models for hydrological purposes***", submitted to Időjárás

Papers in preparation:

- Taşcu S., Y. Wang, Ch. Wittmann, F. Weidle: "***Forecast skill of regional ensemble system comparing to the higher resolution deterministic model***", in preparation for a local meteorological journal (Romania)
- Wang Y., M. Belluš, Ch. Wittmann, J. Tang, F. Weidle, F. Meier, F. Xia, E. Keresturi: "***Impact of land surface stochastic physics in ALADIN-LAEF***", in preparation for Quarterly Journal of the Royal Meteorological Society

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Publications

RC LACE Predictability Area - stay reports (2017):

- Martin Dian, 2017: ***Supersaturation problem in models with SPPT***, Report on stay at ZAMG, 27/03~21/04, 2017, Vienna, Austria
- Martin Belluš, 2017: ***IC and model perturbations for new ALADIN-LAEF***, Report on stay at ZAMG, 24/04~19/05, 2017, Vienna, Austria
- Mihály Szűcs, 2017: ***Implementation of Stochastic Pattern Generator (SPG) in ALADIN code***, Report on stay at ZAMG, 12/06~21/07, 2017, Vienna, Austria
- Raluca Pomaga, 2017: ***Revision of ALADIN-LAEF multiphysics and its combination with SPPT***, Report on stay at ZAMG, 10/07~04/08, 2017, Vienna, Austria
- Simona Taşcu, 2017: ***Revision of LAEF multiphysics***, Report on stay at ZAMG, 10/07~14/07, 2017, Vienna, Austria

Future plans

The main topics for 2018:

- Validation and tuning of 3DVar within ALADIN-LAEF framework in order to be used in ENS BlendVar.
- Preserving relative humidity during the stochastic perturbation to eliminate drying effect.
- Background model error statistics in the EPS framework, e.g. flow-dependent B-matrix computation.
- Operational implementation of ALADIN-LAEF 5 km - phase II (IC upper-air: ENS BlendVar instead of BB cycle).
- Stochastic perturbation of physics tendencies with the use of improved random number generator (SPG).
- Other options to perturb model, e.g. parameter and/or process based stochastic physics for AROME-EPS.
- Implementation of 3D version of new SPG to have vertical structure for random patterns.
- Non-Gaussian noise distribution option for the meteorological fields which do not have normal statistical distribution.
- Development of verification tools for both ALADIN-LAEF and AROME-EPS forecasts.
- Pre-operational implementation of AROME-EPS on new HPC at ZAMG.
- Organize RC LACE working days in the area of EPS (Vienna).

Thank you for your attention!