Regional Cooperation for Limited Area Modeling in Central Europe

LACE
nwp central europe

Recent activities on LAM-EPS in LACE

Martin Belluš with contributions of A. Trojáková, M. Szűcs, Ch. Wittmann, F. Weidle, Y. Wang, C. Wastl, S. Taşcu and E. Keresturi

DHMZ SHMU OMSZ ZAMG ROMANIA ANM

Overview of activities

Our research in 2016 has been mostly focused on the ALADIN-LAEF system upgrade towards the higher resolution LAM EPS, defining new computational domain and implementing new methods for IC uncertainty simulation (BlendVar) and model uncertainty simulation (new stochastic pattern).

Work organized in 6 main subjects:

1. Optimization of ALADIN-LAEF
2. ALADIN-LAEF maintenance
3. AROME-EPS
4. EPS Verification
5. Collaborations
6. Publications

- ❑ Future plans (2017)

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1. Optimization of ALADIN-LAEF

This subject summarizes ongoing tasks of the ALADIN-LAEF research and development. Achieved results, new tested implementations and gained expertise are going to be used for the further improvement of our regional ensemble forecasting system.

Actual topics:

- IC perturbations by 3DVAR in ALADIN-LAEF
- New high resolution ALADIN-LAEF on CY40T1 with ALARO-1 physics
- Optimization of ALADIN-LAEF at 5 km horizontal resolution

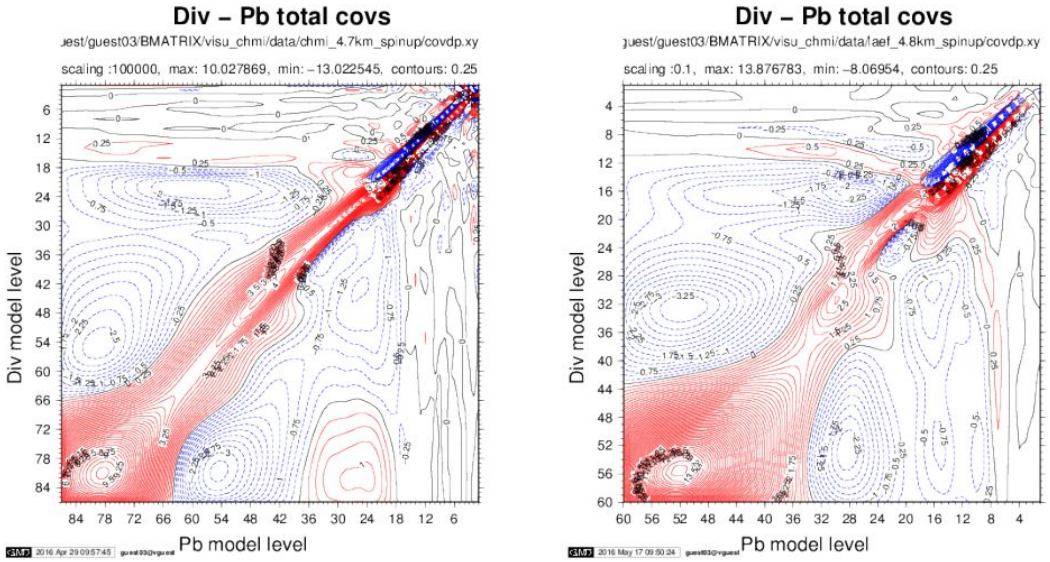
1. Optimization of ALADIN-LAEF

IC perturbations by 3DVAR in ALADIN-LAEF:

The operational ALADIN-LAEF system uses spectral breeding-blending technique for the upper-air IC perturbations. The idea is to upgrade it by the ensemble of upper-air data assimilation (EDA) using 3DVar technique to capture the IC uncertainty.

Background error statistics (B-matrix):

- ❏ Computation validated at ECMWF for CY40T1
- ❏ Ensemble approach for 1 month period
- ❏ B-matrix sampled by 256 ALADIN-LAEF 12h forecast differences (16 members)
- ❏ Diagnostics checked against ALADIN/CHMI



Mean vertical cross-covariance between divergence and vorticity-balanced for ALADIN/CHMI (left) and ALADIN-LAEF 5 km (right).

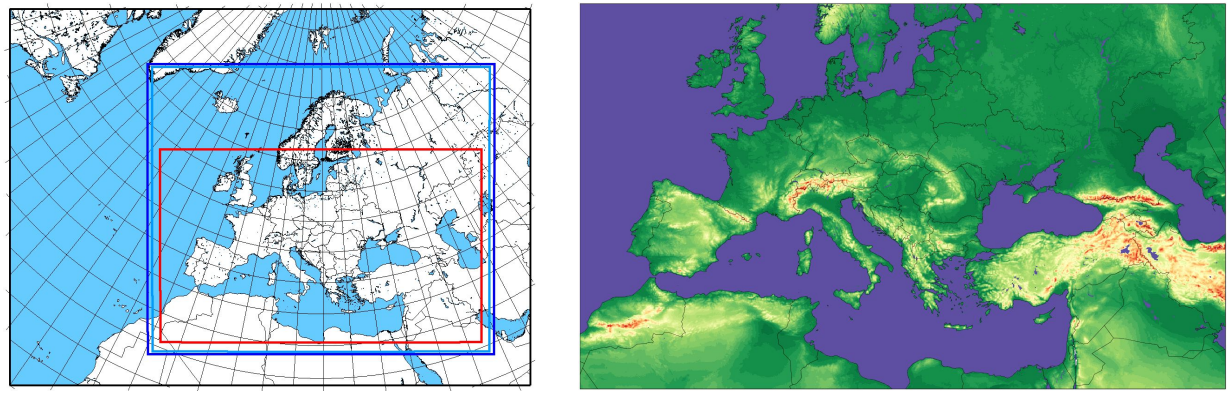
1. Optimization of ALADIN-LAEF

New high resolution ALADIN-LAEF on CY40T1 with ALARO-1 physics:

The technical upgrade of ALADIN-LAEF system towards the higher resolution (5 km, 60 vertical levels) was our main goal for 2016. However, it was not an easy task to meet all the geographical, political and technical requirements concerning the new high resolution LAEF domain.

- ❏ New domain defined (as a subdomain of current one)
- ❏ ALADIN-LAEF upgraded to CY40T1 (pre-bf6)
- ❏ Change of quadratic grid to linear
- ❏ Blending truncation recomputed for new resolution
- ❏ CLIM files prepared at Météo-France (new domain, blending)
- ❏ Tested on historical data set (15 May ~ 15 June, 2011)
- ❏ Compared against the reference (11 km LAEF) and pure downscaling to 5 km

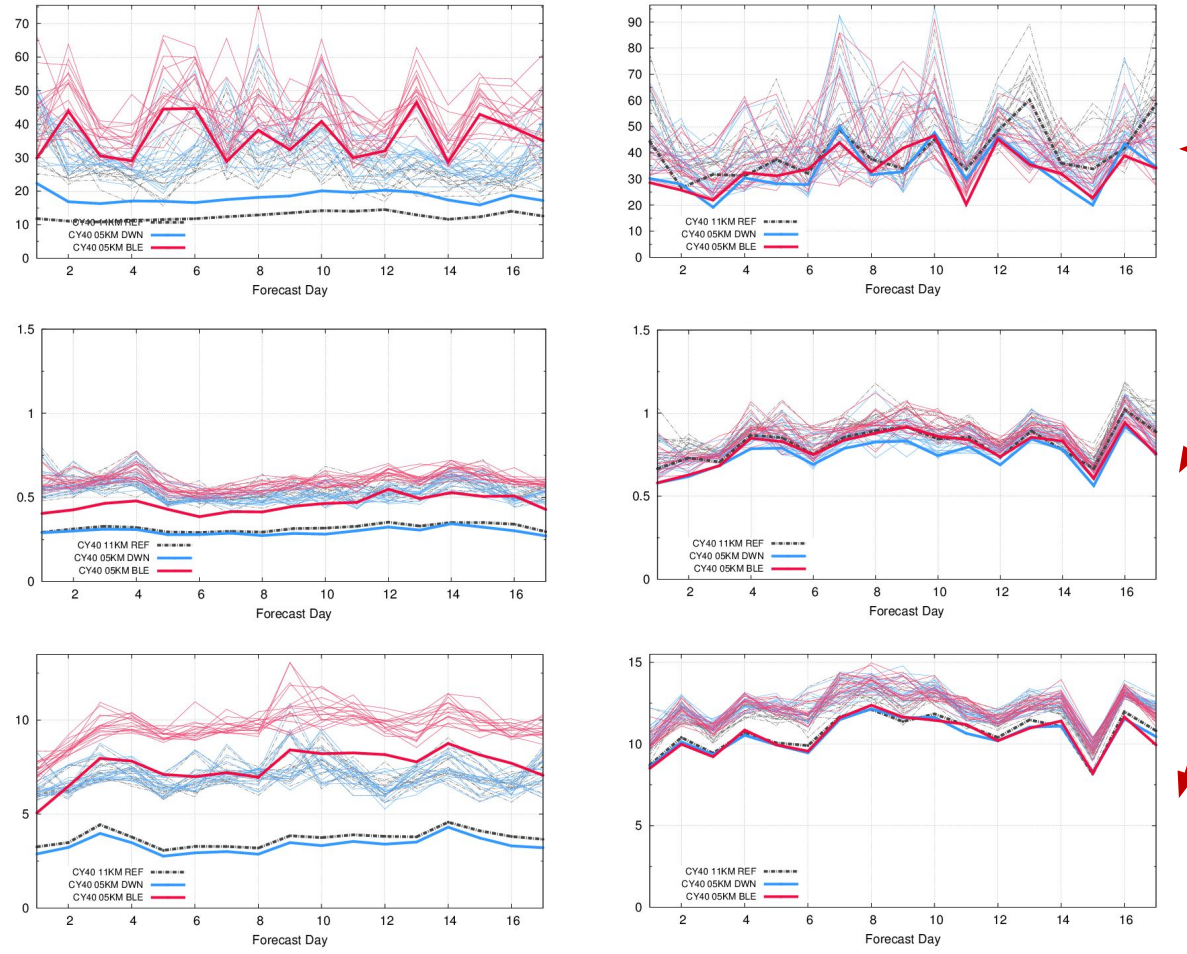
Δx = 4.8 km
vlev = 60



Current operational 11 km ALADIN-LAEF domain borders (blue) with the nested new 5 km domain (red) - left, and the model orography of the new domain - right.

1. Optimization of ALADIN-LAEF

New high resolution ALADIN-LAEF on CY40T1 with ALARO-1 physics:



Geopotential 850 hPa

Temperature 850 hPa

R Humidity 850 hPa

Daily RMSE scores at 850 hPa level for the first 17 days of the experiment (11 km LAEF - dashed, 5 km LAEF downscaling - blue, 5 km LAEF blending cycle - red) for Geopotential (first row), Temperature (second row) and Relative Humidity (third row). The first column is the initial-time output (00) and the second column is +18h forecast.

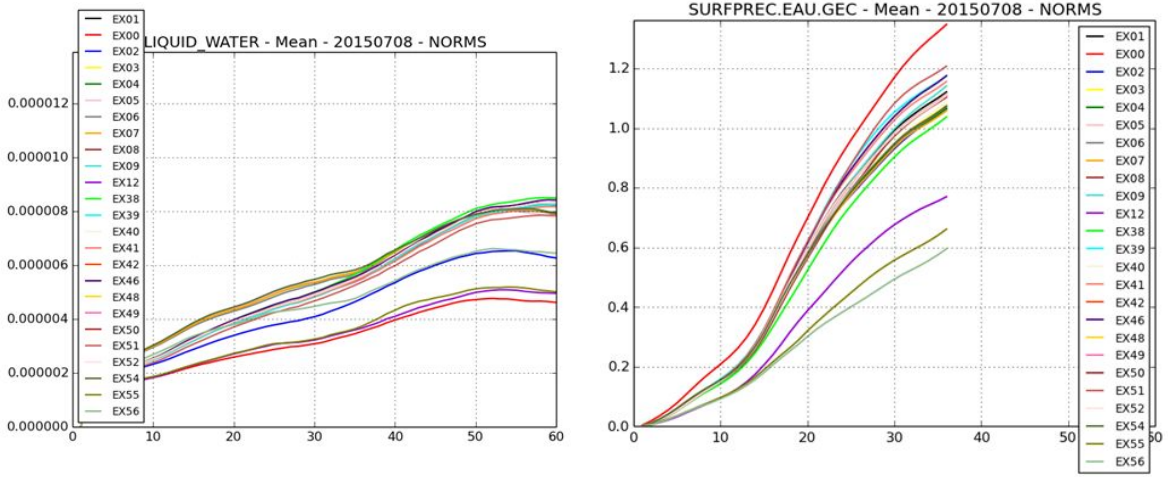
1. Optimization of ALADIN-LAEF

Optimization of ALADIN-LAEF at 5 km horizontal resolution:

In the current ALADIN-LAEF system we still simulate the model uncertainty by the different combinations of physical parameterizations. That is quite a difficult task for the maintenance especially if some of them are bound to already obsolete schemes or are inappropriate for a higher horizontal resolutions.

In the frame of new 5 km ALADIN-LAEF:

- Small sets of namelists created from ALARO-1 using just a few namelist changes
- The most promising sets combined with SPPT
- Target on convection, microphysics and turbulence
- ALARO-1 vs. ALARO-0 difference used for impact judgement
- Avoid clustering of members as far as it is possible
- Tested on new ALADIN-LAEF 5 km domain (CY40T1_bf6)
- 2 weeks period with intense convective cases (15 May ~ 01 June, 2016), 6 versions tested



The examples of norms used for the impact tests, where "EX00" is the ALARO-0 reference (red) and "EX01" is the ALARO-1 reference (black), the rest of the experiments are different tested configurations.

1. Optimization of ALADIN-LAEF

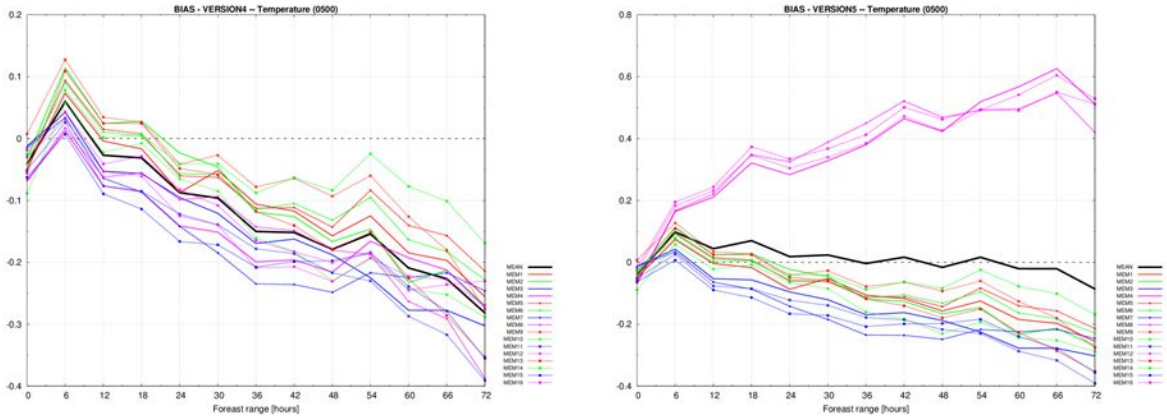
Optimization of ALADIN-LAEF at 5 km horizontal resolution:

VERSION 4					VERSION 5				
	used for members					used for members			
EXP57	01	05	09	13	EXP57	01	05	09	13
EXP01	02	06	10	14	EXP01	02	06	10	14
EXP55	03	07	11	15	EXP55	03	07	11	15
EXP58	04	08	12	16	EXP00	04	08	12	16

16 EPS members

The construction of multiphysics versions 4 (left) and 5 (right).

- EXP57 – ALARO-1 modified turbulence
- EXP01 – ALARO-1 reference
- EXP55 – ALARO-1 modified microphysics + deep convection
- EXP58 – ALARO-1 modified turbulence, microphysics and deep convection
- EXP00 – ALARO-0 reference



Temperature BIAS at 500 hPa for the ensemble version 4 (left) and version 5 (right).

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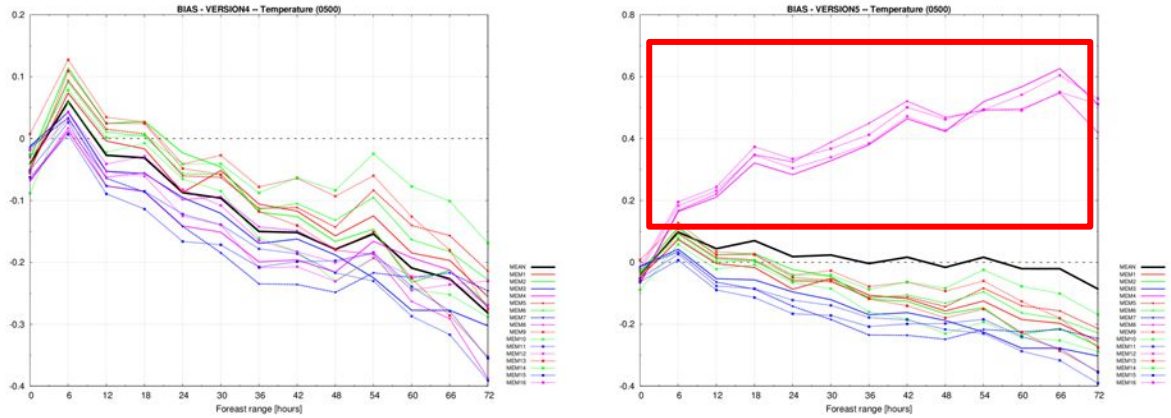
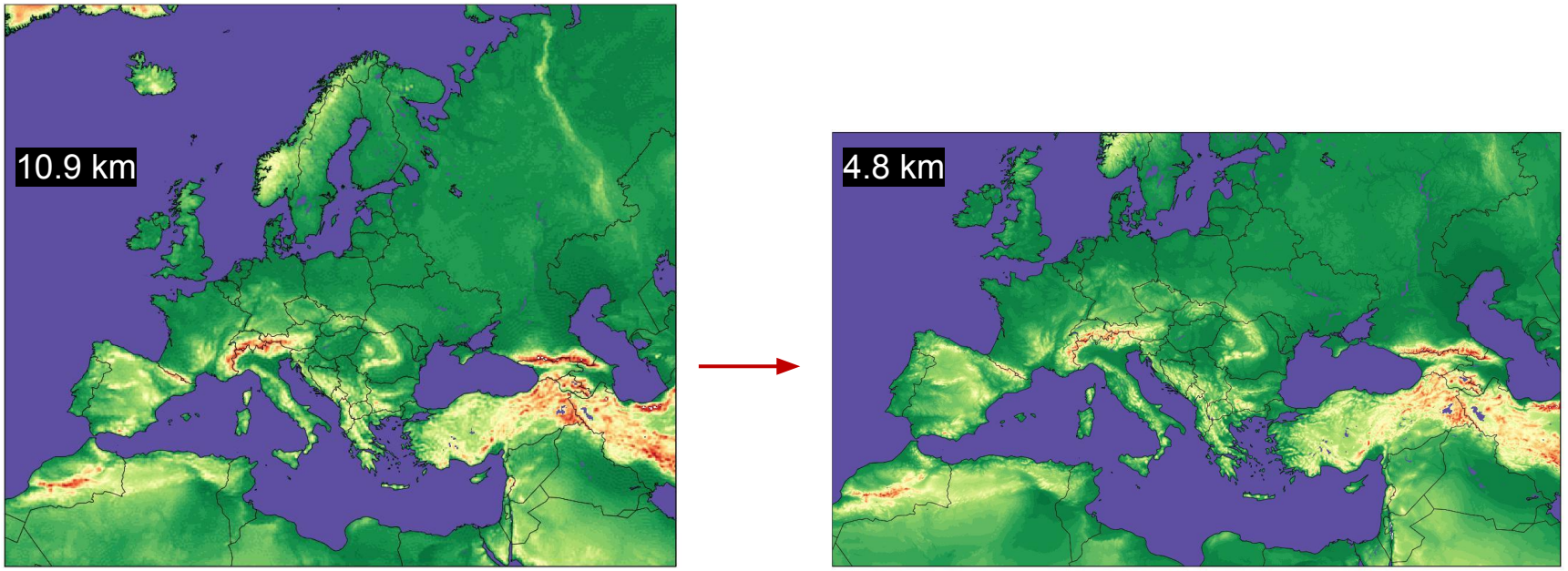


Temperature BIAS at 500 hPa for the ensemble version 4 (left) and version 5 (right).

2. ALADIN-LAEF maintenance

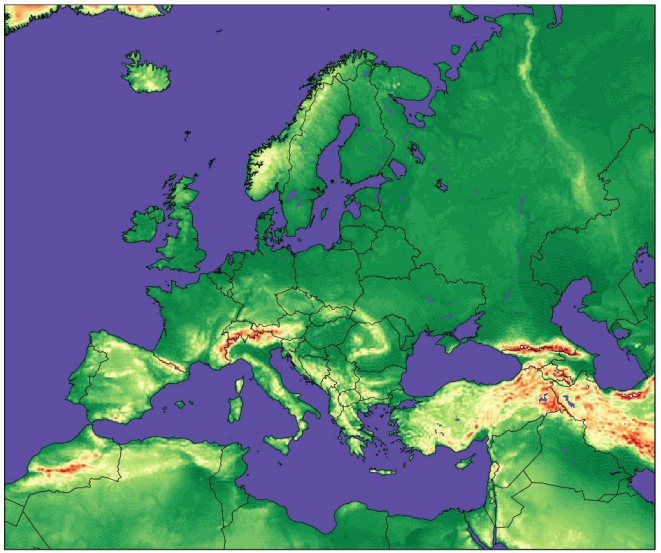
The main objective of this task is to maintain and monitor the operational suite of ALADIN-LAEF running at ECMWF HPC facility. As a result a stable operational suite of ALADIN-LAEF is guaranteed and the delivery of probabilistic forecast products (GRIB files, plots) for the LACE partners is ensured.

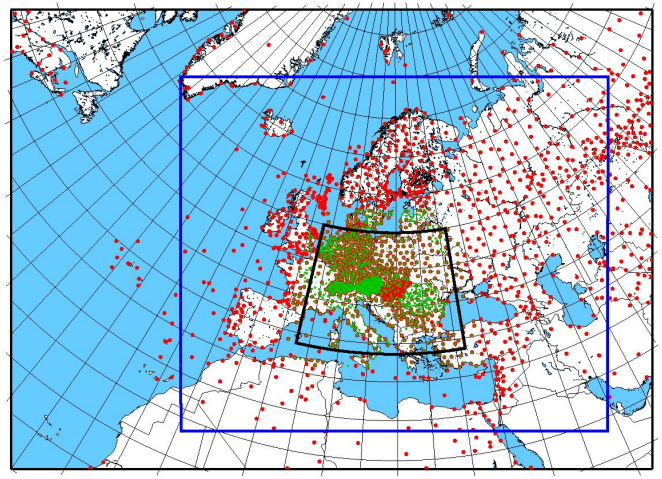
In 2016 we have technically upgraded ALADIN-LAEF to new computational domain with 5 km horizontal resolution and 60 vertical levels. We have updated its components to CY40T1 with the use of ALARO-1 physics and changed the grid type finally to linear. However, a lot of work still needs to be done in order to make all those changes operational.



2. ALADIN-LAEF maintenance

ALADIN-LAEF (LACE, operational on CRAY HPCF)	
ensemble size	16 + 1
Δx / vertical levels	10.9 km / 45
time-lagged coupling	ECMWF EPS (6h frequency)
runs per day	00 and 12 UTC (+72h forecast)
IC perturbation	surface: ● ESDA by CANARI (T2m, RH2m) upper air: ● breeding-blending
model perturbation	Multi-physics (16 different namelists): ● micro-physics ● deep/shallow convection ● radiation ● turbulence





3. AROME-EPS

This task covers quite wide area of research and development regarding convection-permitting ensembles. Such high-resolution ensembles utilizing non-hydrostatic model AROME are developed concurrently at OMSZ and ZAMG institutes.

Actual topics:

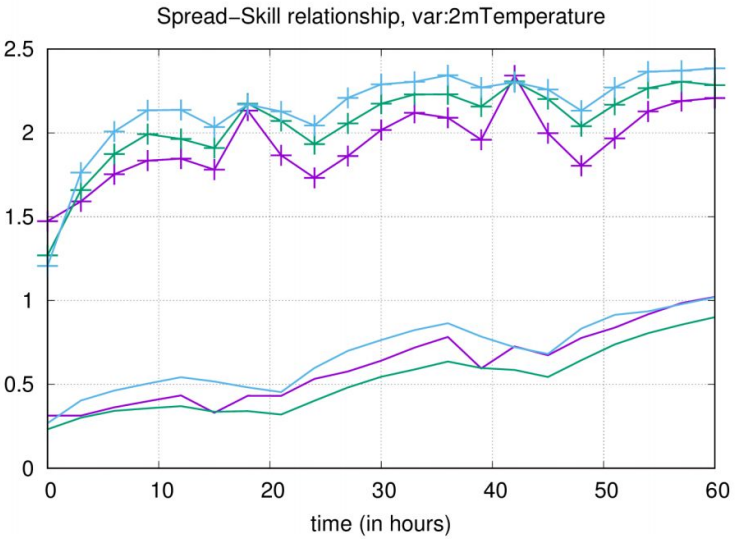
- Developments at OMSZ related to ensemble systems
- AROME-EPS experiments at ZAMG
- Stochastic pattern generators

3. AROME-EPS

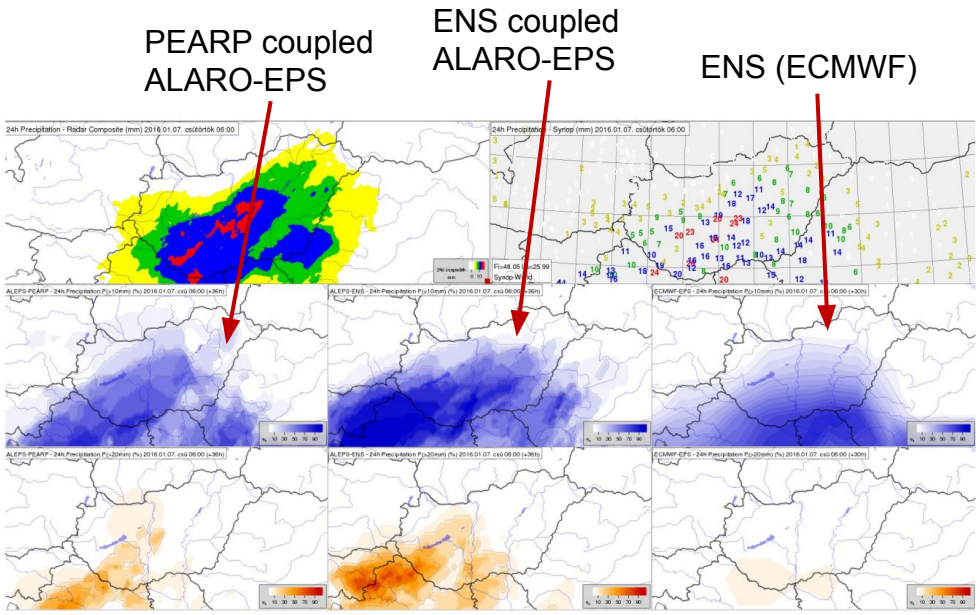
Developments at OMSZ related to ensemble systems:

ALARO-EPS (8 km hydrostatic) will be in operation till a new machine is available at OMSZ, where an high-resolution AROME-EPS can smoothly run. Therefore, some tests mainly with ALARO-EPS were performed concerning the topics:

- ECMWF-EPS boundary conditions tests (PEAPR vs ENS coupling)
- Ensemble data assimilation
- Stochastic perturbation of physics tendencies



Spread-skill relationship of T2m. ENS with 11 members (purple), ENS coupled ALARO-EPS (green), PEARP coupled ALARO-EPS (blue). Verification period: 11 Dec, 2015 - 31 Jan, 2016.



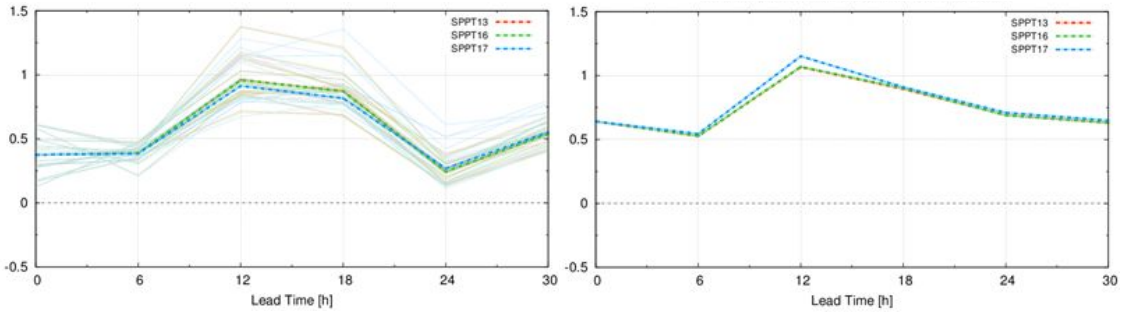
24h precipitation amount at 06 UTC of January 07, 2014. Upper line: radar measurement (left) and SYNOP (right). The corresponding ensemble derived probabilities for 10 mm (middle row) and 20 mm (bottom row) thresholds.

3. AROME-EPS

AROME-EPS experiments at ZAMG:

For an operational setting the computing resources at ZAMG are not sufficient, one has to wait for a new HPC which should come in 2017. For now only non-operational AROME-EPS experiments were done at ZAMG and at the ECMWF HPCF, with the following configuration:

- 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 (time-lagged 6h)
- Coupling frequency: 3h



Temperature at 2m BIAS (left) and ensemble SPREAD (right) for the tapering function sensitivity experiments. Partial tendencies with tapering in PBL and stratosphere switched on (red), tapering only in PBL (green) and with the tapering function switch off completely (blue).

Experiments:

- SPPT (total tendencies) - optimization of stochastic pattern for AROME Austria domain (MF settings not suitable; big BIAS and RMSE; generally small effect of SPPT)
- SPPT (partial tendencies) - perturbing shallow convection, turbulence and microphysics separately (hardly no differences between total and partial tendencies but model is more stable)
- Influence of tapering function investigated (reduced BIAS and increased SPREAD at 2m; unstable model with total tendencies)

3. AROME-EPS

Stochastic pattern generators:

In order to simulate the model uncertainty, the stochastic perturbations can be added on the top of the total tendencies like in the operational implementations or to partial tendencies like in many tests. Nevertheless, independently of an applied perturbation method, the characteristics of used random numbers are crucial.

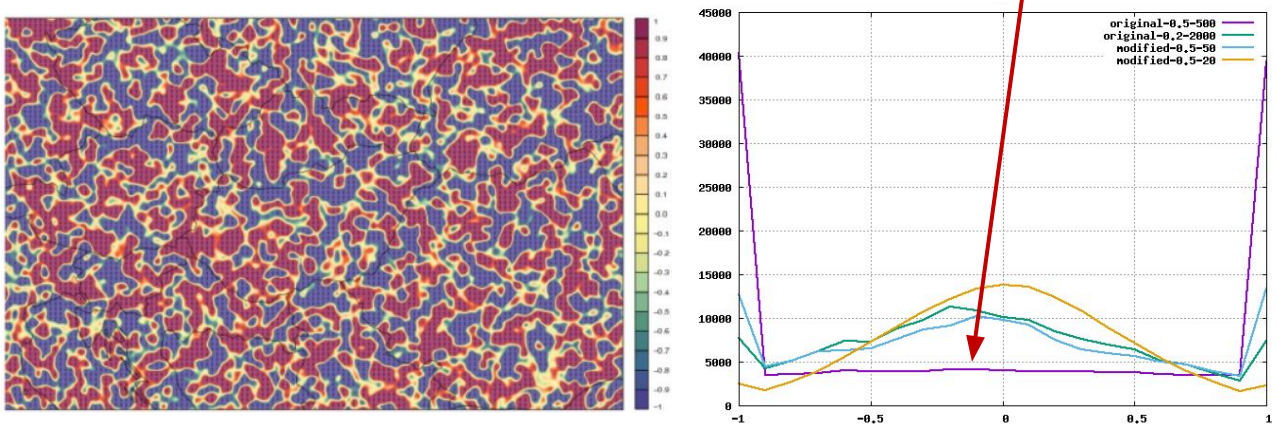
Features of current random number generator for SPPT:

- Gaussian distribution
- Standard deviation (σ) controlled via namelist
- Horizontal (L) and temporal (τ) correlation controlled via namelist
- At least two of the controlled parameters do not work properly

Problematic issues:

- Horizontal correlation is smaller than expected
- Too many spots with random numbers +1 or -1 (discrete values)

U-shaped distribution
(clipped data)



Spectral pattern in AROME model with the original spectral pattern generator (σ=0.5 and L=500 km) - left, and histogram of random numbers for current export version with default settings (purple).

3. AROME-EPS

To tackle the mentioned issues, there were two actions taken:

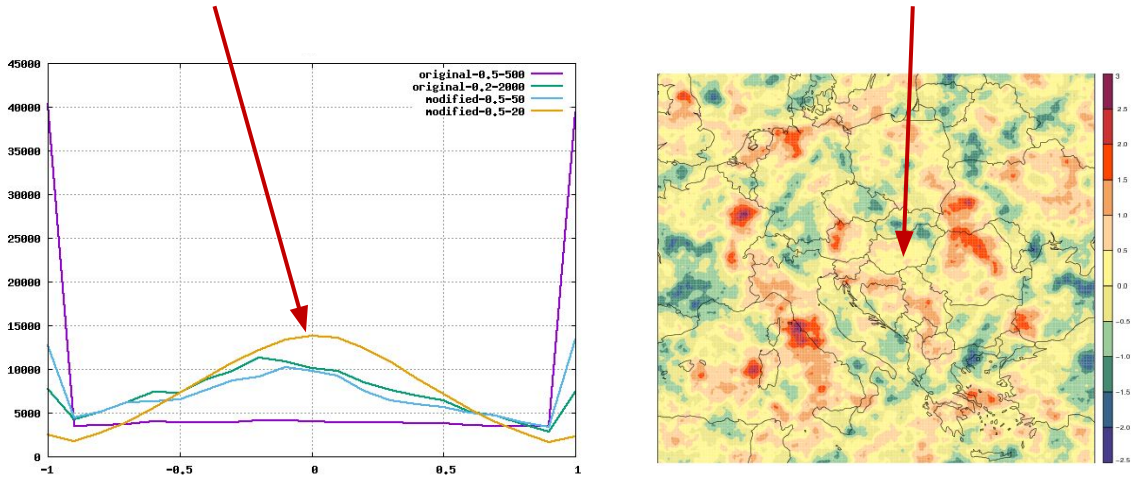
- Current spectral random number generator was (firstly tuned) modified
- New approach was tested (different method to obtain random numbers has been implemented*)

(*) Stochastic pattern generator (SPG, Tsyrulnikov and Gayfulin, 2016):

- Its basic solver is also spectral-space based
- It is developed for the LAMs
- The acceptable range of correlation values is wider than in our current pattern generator
- It has 2D and 3D in space versions as well and the generated noise is theoretically Gaussian

Bell-shaped distribution

Better horizontal correlation



Histogram of random numbers for current export version with revised setting (green) compared to the modified version with very-long horizontal correlation length (blue) and moderate horizontal correlation length (orange) - left, and random field generated by SPG (as an external program) with the LACE domain specific configuration - right.

5. Collaborations

This task covers activities merging different areas, collaboration with other consortia, applications, projects.

Actual topics:

- SRNWP-EPS phase II project of EUMETNET
- Collaboration with the HIRLAM EPS group

5. Collaborations

SRNWP-EPS phase II project of EUMETNET:

- Workshop on “Probabilistic prediction of severe weather phenomena” in Bologna (Italy), 17-19 May, 2016
- Probabilistic prediction of severe weather events with focus on fog and thunderstorms
- Project participants will identify one or two test periods including cases of significant weather events
- Different cases for each NMSs, but including similar phenomena
- Testing the impact of their own perturbation methods using their own ensemble system
- The lists of case studies, perturbation methods and results will be shared
- Progress discussion will take place on Thursday afternoon (ET SRNWP-EPS II, ET-EPS of C-SRNWP)

Collaboration with the HIRLAM EPS group:

- Exchanging our scientific plans and the ideas (HARMON-EPS WW, 21-25 Nov, 2016, FMI Helsinki)
- Agreed on a closer cooperation regarding the topics where both sides can profit from each-other
- The simplified ALADIN-LAEF multi-physics setup was already tested in HARMON EPS framework

6. Publications

The scientific achievements of the LACE EPS R&D activities are being presented at the international workshops and published in the scientific journals.

Status for this year:

- 3 published papers
- 1 accepted
- some other papers planned or already in progress

6. Publications

Published papers:

- Belluš M., Y. Wang, F. Meier, 2016: "Perturbing surface initial conditions in a regional ensemble prediction system", Monthly Weather Review, 144, 3377–3390, DOI: http://dx.doi.org/10.1175/MWR-D-16-0038.1 (published in September 2016)
- Schellander-Gorgas T., Y. Wang, F. Meier, F. Weidle, Ch. Wittmann, and A. Kann, 2016: "On the forecast skills of a convection permitting ensemble", Geosci. Model Dev. Discuss., DOI:10.5194/gmd-2016-191 (published in August 2016)
- Szűcs M., P. Sepsi, A. Simon, 2016: "Hungary's use of ECMWF ensemble boundary conditions", ECMWF Newsletter No. 148 – Summer 2016, 24-30, http://www.ecmwf.int/sites/default/files/elibrary/2016

Accepted papers waiting for the publication:

- Szűcs M., A. Horanyi, G. Szépszó, 2015: "Ensemble forecasting in numerical weather prediction", Mathematical Problems in Meteorological Modelling, Springer (accepted in 2016)

Papers in preparation for the submission:

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

Future plans (2017)

- Validate BlendVar within the full ALADIN-LAEF suite
- Implement OBS perturbation for EDA (upper-air)
- Do quality control for OBS used in 3DVar
- Investigate different possibilities for B-matrix sampling (flow-dependent B)
- Use new multiphysics (ALARO-1) to simulate model uncertainty
- Investigate a stochastic perturbation at the process level
- Continue work on new SPG implementation for LAM EPS
- Perform experiments with convection-permitting EPS
- Continue collaboration with HIRLAM EPS group
- Apply the results of R&D into our operational systems

Grazie per l'attenzione!