Working Area Predictability

Progress Report

Prepared by:	Martin Belluš with contributions of Alena Trojáková, Mihály Szűcs, Christoph Wittmann, Florian Weidle, Yong Wang, Clemens Wastl, Simona Taşcu and Endi Keresturi
Period:	2016 (final)
Date:	March 2017

Progress summary

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).

In 2016 there were five LACE stays executed by Predictability working group, all of them were hosted by ZAMG. Martin Belluš (SHMU) spent 4 weeks preparing new high resolution domain for ALADIN-LAEF and upgrading the whole system to CY40T1 ALARO-1 including new BlendVar assimilation cycle. Alena Trojáková (CHMU) spent 4 weeks implementing 3DVar data assimilation technique into the ALADIN-LAEF framework along with the B-matrix computations. Simona Taşcu (NMA) spent 8 weeks with the optimization of ALADIN-LAEF at 5 km horizontal resolution. Mihály Szűcs (OMSZ) spent 4 weeks investigating the known limitations/issues of the current stochastic pattern generator (SPPT scheme) and he has already started with the implementation of a new pattern generator (Tsyrulnikov-Gayfulin, 2016). Martin Belluš (SHMU) spent another 4 weeks investigating the technical issues regarding new ALADIN-LAEF system and discovered the bug in CY40T1 (including the newer cycles) in the quadratic coupling interpolation.

In addition to the regular RC LACE stays, Christoph Wittmann (ZAMG) supervised the work of Simona Taşcu (NMA) and Canberk Karadavut (MGM) on multi-physics based on the new ALARO-1 code, and Florian Weidle (ZAMG) have been securing the operational production of ALADIN-LAEF system running at ECMWF HPC facility. Furthermore, the work on convection-permitting AROME-EPS was carried out locally at ZAMG (Clemens Wastl) and OMSZ (Mihály Szűcs).

The long term effort, which has been put into the research in the area of ensemble forecasting, was rewarded by the successful publication of several scientific papers in peer-reviewed journals. The paper "On the forecast skills of a convection permitting ensemble" (Schellander-Gorgas, Wang, Meier, Weidle, Wittmann, Kann) was published in Geoscientific Model Development in August 2016. Another paper "Perturbing surface initial conditions in a regional ensemble prediction system" (Belluš, Wang, Meier) was published in Monthly Weather Review in September 2016. An article "Hungary's use of ECMWF ensemble boundary conditions" (Szűcs, Sepsi, Simon) was published in ECMWF Newsletter, Summer 2016 edition and the paper "Ensemble Methods in Meteorological Modelling" (Szűcs, Horanyi, Szépszó) was published in special issue of Mathematical Problems in Meteorological Modelling by Springer.

Scientific and technical main activities and achievements, major events

S1 Action/Subject/Deliverable: Optimization of ALADIN-LAEF

Description and objectives: This subject summarizes ongoing and completed 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.

- **IC perturbations by 3DVAR in ALADIN-LAEF:**

The operational ALADIN-LAEF system uses spectral breeding-blending technique for the upper-air initial condition perturbations (IC). We aim to further extend the methodology by the ensemble of upper-air data assimilation (EDA) using the 3DVar technique to capture the IC uncertainty.

The background error statistics (B-matrix) are fundamental component of the 3DVar. Firstly the programs and scripts for B-matrix computation were validated at ECMWF for CY40T1. The B-matrix was computed by ensemble approach following Berre (2000) for one month period. The period was constrained by available ALADIN-LAEF LBCs to 15 May - 15 June 2011, 12 UTC runs only. Altogether 256 ALARO downscaled 12h forecast differences from 16 members ($m_i - m_{i+1}$, where i = 1, 3, ..., 15) were used for B-matrix sampling. The 12h differences were considered, because the ALADIN-LAEF uses 12h production forecast as the first guess for production analysis. Some typical diagnostics were checked with respect to the operational background errors used in ALADIN/CHMI and although both setups are very different, computed ALADIN-LAEF B-matrix looks qualitatively comparable (see Fig. 1).

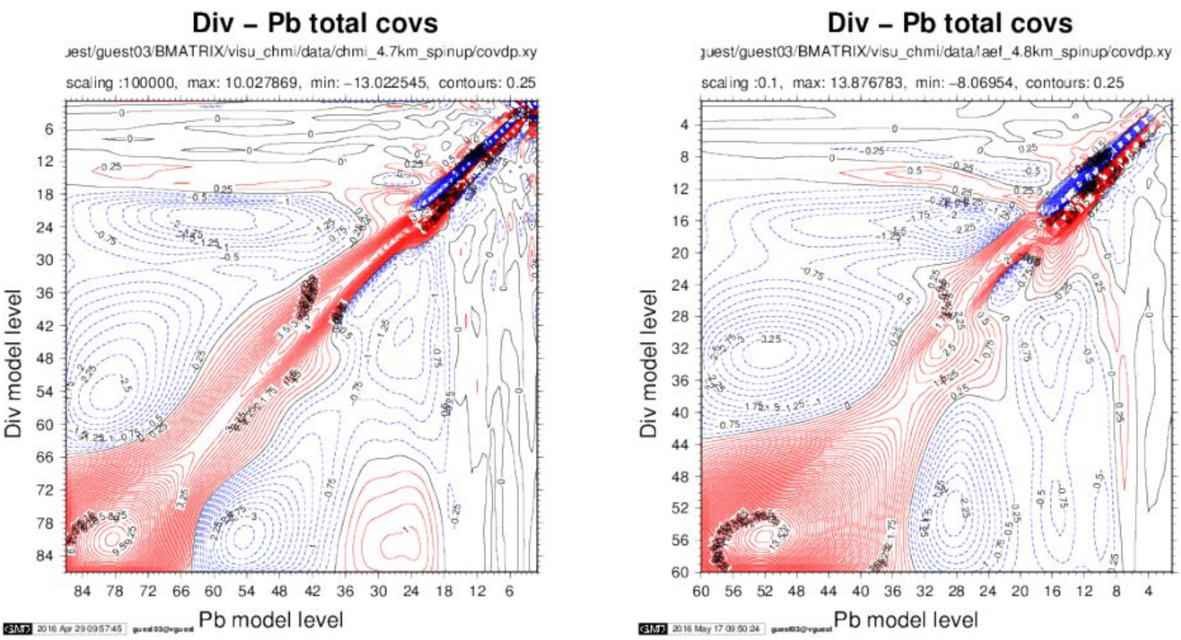


Figure 1: Mean vertical cross-covariance between divergence and vorticity-balanced for ALADIN/CHMI (left) and ALADIN-LAEF 5 km (right).

❑ 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. In order to make possible a comparison of our experiments on new 5 km domain (including the implementation of Ensemble BlendVar) with the previous experiments on historical data from summer 2011 on 11 km domain, it was decided to couple it firstly to the historical data set. Therefore, new 5 km LAEF domain was constructed to fit the current one (see Fig. 2 - left).

Another essential condition was the upgrade of the whole ALADIN-LAEF system to CY40T1 with the use of new ALARO-1 physics. Unfortunately, using CY40T1 (bf05) we came immediately into a problem inside configuration ee927:

```
SUEFPG3 : THERE ARE POINTS OUT OF THE DOMAIN
          OR TOO NEAR OF THE DOMAIN BORDER
 ABOR1 CALLED
 SUEFPG3 : ABOR1 CALLED
```

That was despite of the fact, that we were sure our target domain fits perfectly inside the coupling one (see Fig. 2 - left). Not even the proposed increase of RCO_EZO parameter (in NEMFPEZO namelist) helped to solve the situation. Although, ee927 on CY38T1 with the same input and output domains and the same CLIM files worked like a charm. Eventually, to make the conclusion, we did some code “hacking” in CY40T1 (aware of the fact, that this is just related to a dummy E-zone which has to be setup for the interpolations and then it will be anyway overwritten by a true bi-periodization later). That worked well and we have got the identical results, but nevertheless ee927 from CY38T1 was finally used to create LBCs for our initial experiments for the period 15 May ~ 15 June, 2011.

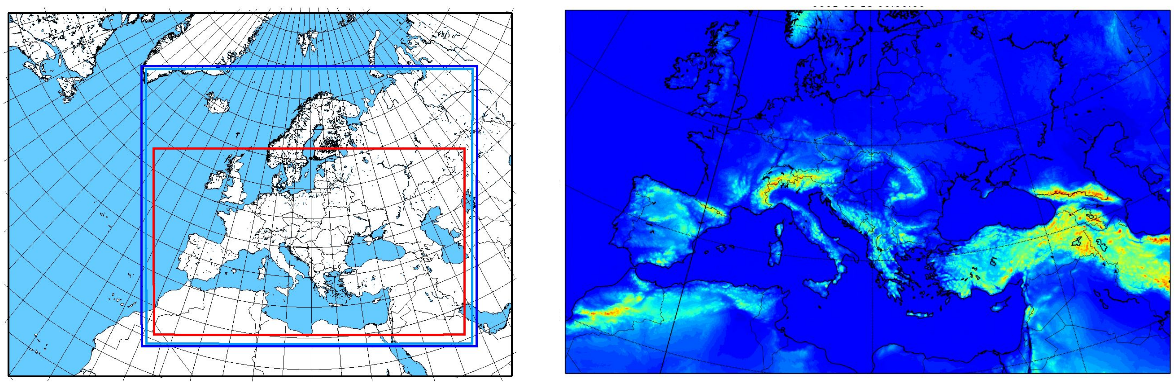
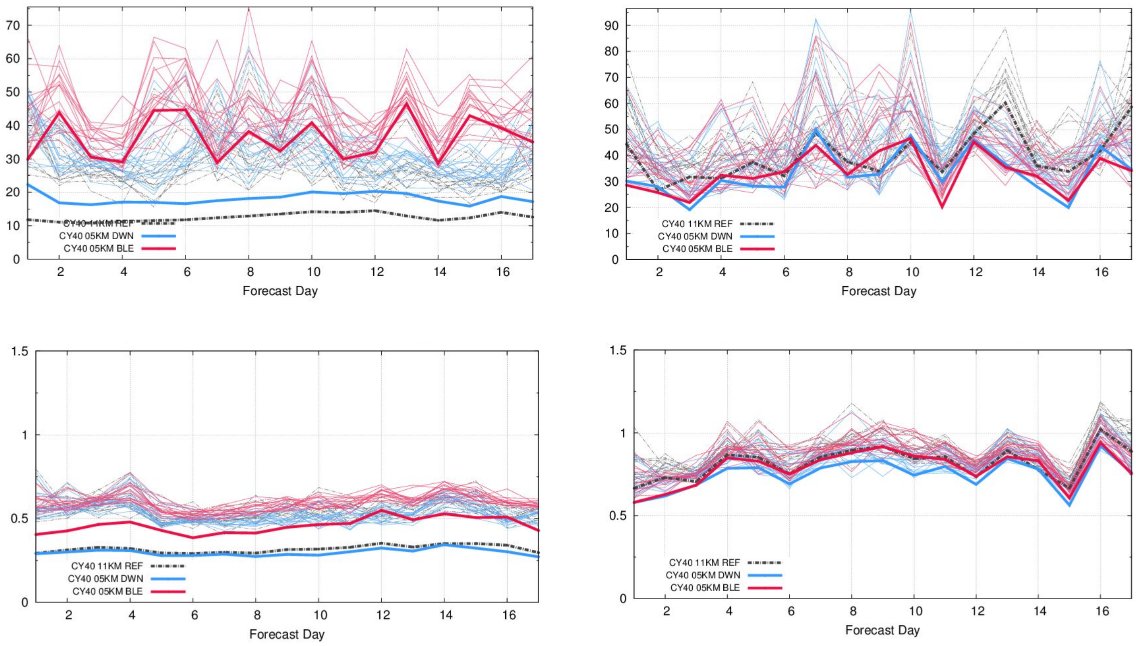


Figure 2: Current operational 11 km ALADIN-LAEF domain borders (blue) with the nested new 5 km domain (red) - left, and the model orography of the new domain - right.

As a next step, the blending truncation had been recalculated for the new LAEF domain, taking into account its changed geometry. This time we have finally upgraded also the grid type from quadratic to linear, which affects the computation as well. ECMWF's recently increased grid-point resolution of EPS forecast did not affect the computation since the spectral resolution of EPS forecast was not changed (T_L639 => $T_{CO}639$) and nor the truncation of the singular vectors (T_L42).

Upper-air spectral blending for the new 5 km ALADIN-LAEF domain was tested within the historical data set (15 May ~ 15 June, 2011) and compared against the reference (11 km LAEF) and pure downscaling (see Fig. 3). Unfortunately, according to the first verification results it was clear, that the upper-air spectral blending cycle on 5 km domain is not OK. What's more, the scores are even worse in comparison with the pure downscaling. Intensively investigating this kind of problem we have found one by one several possible issues (incorrect CLIM files, missing tuning due to the vertical resolution changes, other minor changes in the namelist), but none of them really helped to improve the situation. All those corrections had only minor impact.

Therefore, we believe that the implementation is correct, but the deterioration of the scores is caused by something else. It might be the design of the experiment itself, while we have used the original LBCs for 11 km LAEF domain (with only 45 vertical levels) for the creation of new boundary conditions for 5 km domain (but with 60 vertical levels). That could probably explain also a bit noisy kinetic energy spectra of involved downscaled files (see Fig. 4).



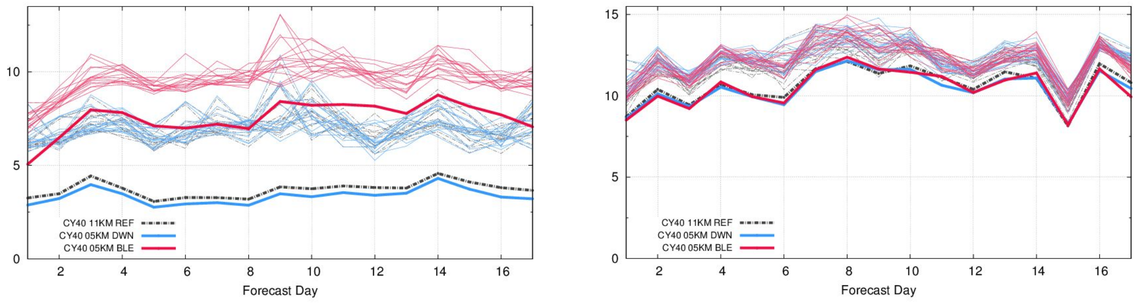


Figure 3: Daily RMSE scores at 850 hPa level for the first 17 days of the experiment (11 km LAEF - dashed, 5 km LAEF downscaling - blue, 5 km LAEF blending cycle - red) for Geopotential (first row), Temperature (second row) and Relative Humidity (third row). The first column is the initial-time output (00) and the second column is +18h forecast.

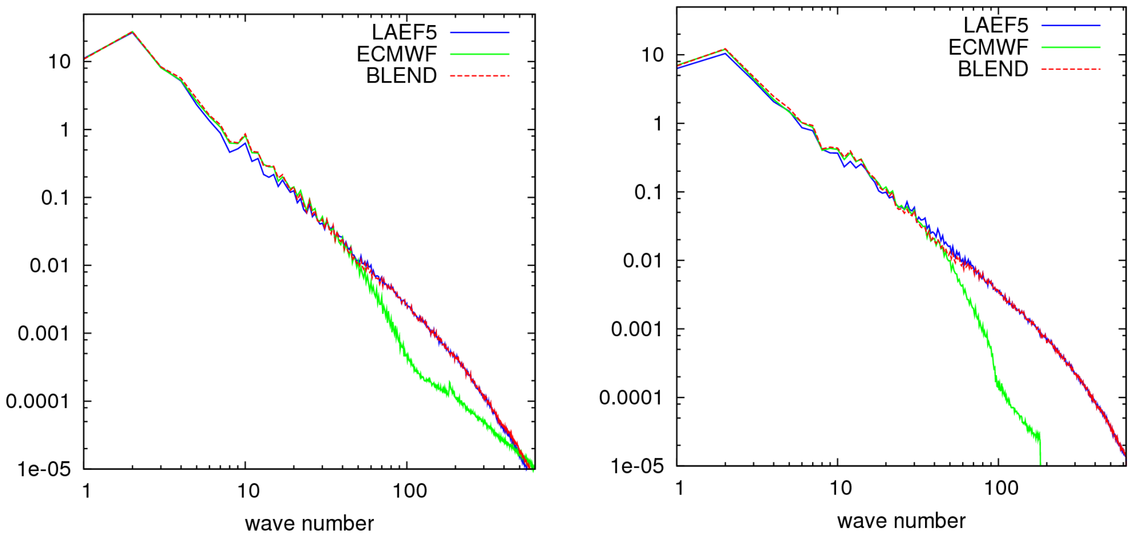


Figure 4: Kinetic energy spectra of all blending input and output files (on new 5 km / 60 levels LAEF domain) for model level 30 (left) and model level 40 (right), member 7, 31 May, 2011, 00 UTC.

Furthermore, new *var3d* script adapted from current LAEF *canari* script was prepared together with Alena Trojáková. New functions like &screen, &minim were added to run screening (3DVar quality control) and minimization (3DVar upper-air data assimilation) respectively. Furthermore, the function &getobs was modified to handle the multiple observation types such as TEMP, SYNOP, AMDAR, etc. Tool for merging the observation data - obsoul_merge (v04) was modified in the way, that an assimilation time window can be now specified via an optional argument "-twindow" (or any unambiguous abbreviation of it). If such argument is not supplied, the default value for observation time window 60 min is used. As before, all observations from the interval <-½ * $twindow, +½ * $twindow> will be accepted by the filter. A technical experiment to perform 3DVar assimilation using conventional data (SYNOP, TEMP, AMDAR) on new 5 km ALADIN-LAEF domain and B-matrix computed from (spoiled) blending experiment was successfully done, but the other work must have been suspended till the above mentioned issue with the inputs is solved.

❑ Spectral blending on high resolution issue:

From the above results it was obvious that we have a problem somewhere within our new ALADIN-LAEF configuration. Unfortunately, due to given circumstances the several major upgrades of the system were done at the same time (new high resolution domain with 4.8 km horizontal grid and 60 vertical levels; switch from quadratic to linear grid; model version upgrade to cy40t1 with ALARO-1 physics and implementation of new perturbation method BlendVar). In other words, it was not quite clear, where the issue could be hidden. Therefore, the following possibilities were investigated:

- ❑ creation of LBCs using the interpolation from 91 vertical levels instead of 45
- ❑ implementation of incremental digital filter initialization (IDFI)
- ❑ discovery of a curious bug in CY40T1 in the quadratic coupling interpolation

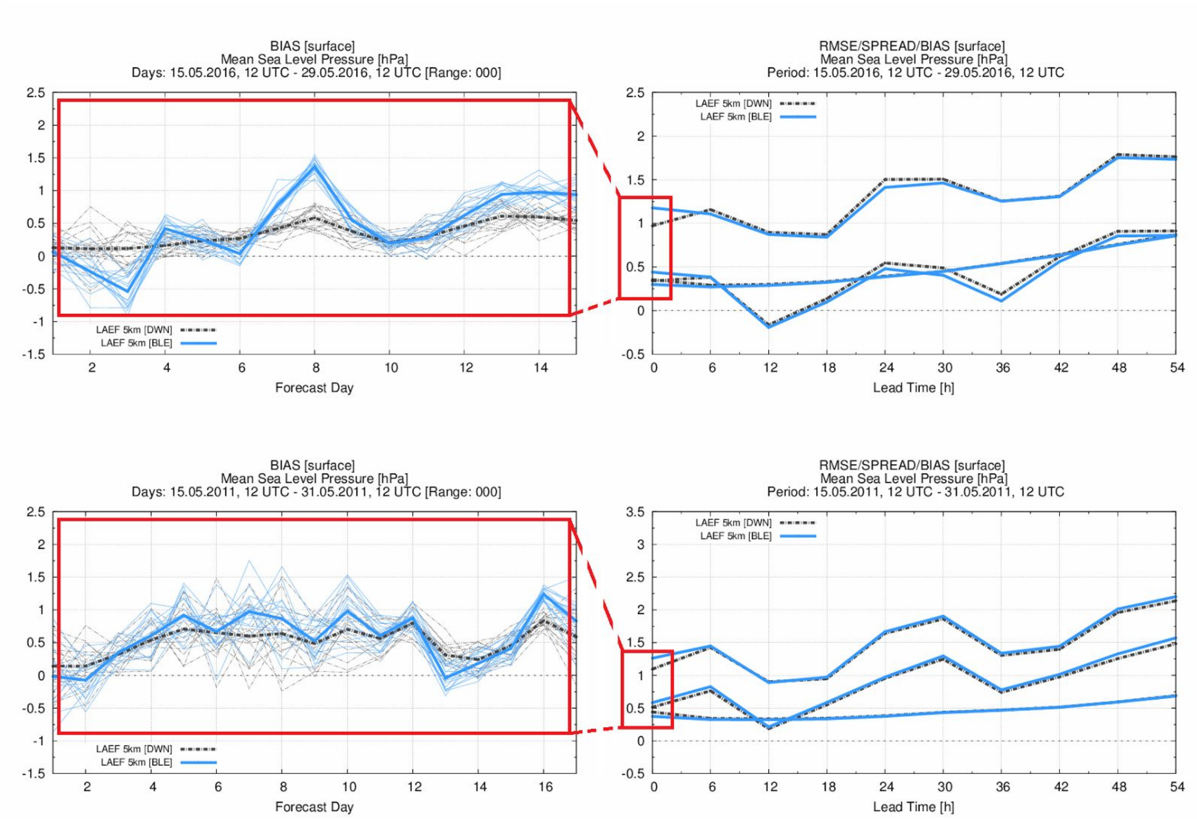


Figure 5: The comparison of MSLP errors when LBCs were interpolated from 91 vertical levels (case 2016, first row) and from 45 vertical levels (case 2011, second row). There is BIAS for initial time along all the experiment days (left) and RMSE, SPREAD, BIAS for the forecast ranges (right). Blue line represents the blending cycle, while the gray dashed line is just the dynamical adaptation for the reference.

As one can see in the above pictures, the results were not satisfactory. In principle, the errors are pretty much the same regardless of vertical resolution of the driving model, be it 45 or 91 levels (see Fig. 5).

In order to decrease these initial errors, an &idfi function was implemented inside the blending procedure within the ALADIN-LAEF system. The general idea of incremental digital filter initialization is rather easy. We need to filter out the high frequency noise from the INIT file, while the high resolution information from the guess has to stay intact. In other words, there were added 2 subsequent steps into the ALADIN-LAEF blending procedure.

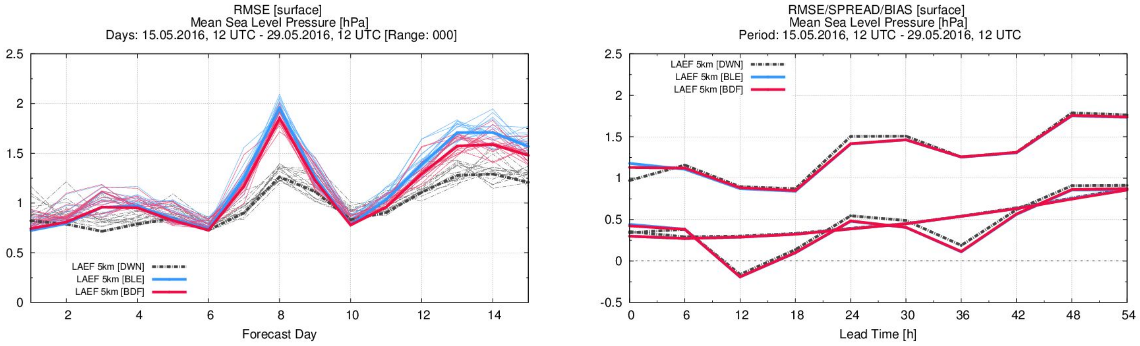


Figure 6: The evaluation of MSLP errors after the application of IDFI for 15-days verification period. The errors at the initial time for each experiment day (left) and for the forecast ranges (right). Blue line is the original blending, while red line is blending enhanced by IDFI functionality. Gray dashed line is just the dynamical adaptation for the reference.

The impact of IDFI can be observed only for the very first hours of integration at best where the errors are slightly reduced. Such behaviour was expected. Unfortunately, this has not solved our primary problem with the initial errors of the model fields, which are significantly higher. However, as a result of our deep investigation of the issue we eventually found a serious bug in CY40T1 inside the coupling procedure, which caused the spurious oscillations of prognostic variables on time-step bases (see Fig. 7).

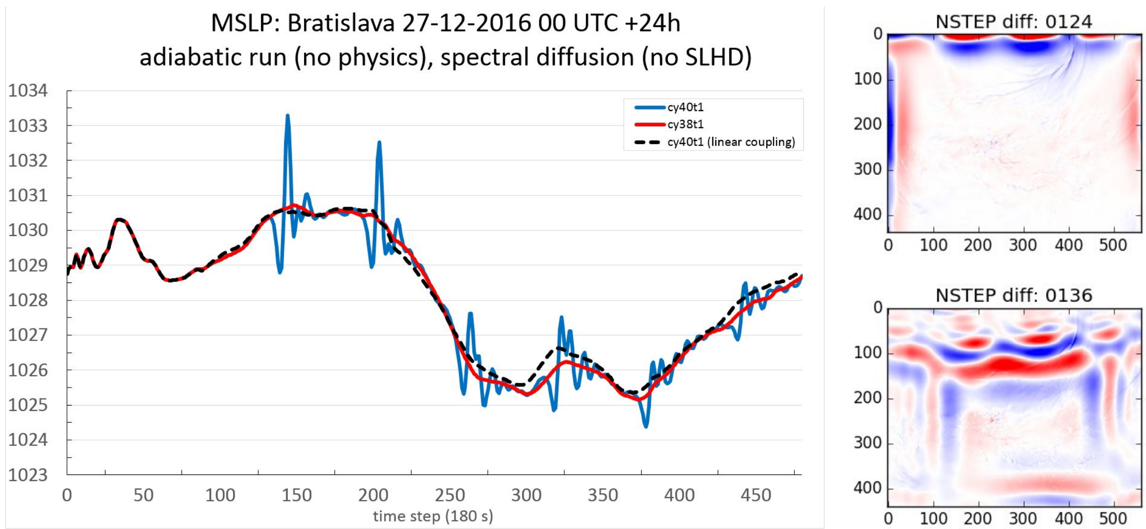


Figure 7: LEFT: Time evolution of MSLP for one selected case at Bratislava airport for each time-step (180 s) up to 24 hours. Blue line is the adiabatic run on CY40T1 with the quadratic coupling interpolation (operational setup), red line is the same but on CY38T1 (without the oscillations) and black dashed line is again on CY40T1 but with the linear coupling used for the whole integration period. RIGHT: Spatial distribution and advection of the artificial signal due to bug in CY40T1 inside the quadratic coupling interpolation procedure (LACE domain).

Thanks to the nature of given bug, the most spoiled model state was unfortunately pushed to the blending cycle as the first guess. Moreover, such high-frequency noise could not have been filtered out by blending.

- ❑ **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. The revision of multiphysics is ongoing procedure, now in the frame of new ALADIN-LAEF at 5 km with the following targets:

- ❑ reduce number of namelists for LAEF multiphysics to ease maintenance (LAEF 11 km uses 16 different namelists!)
- ❑ create small sets of namelists (approx. 4) from ALARO-1 using just a few namelist changes
- ❑ once a first suitable set was found combine it with stochastic physics scheme
- ❑ target on convection, microphysics and turbulence
- ❑ reference: ALARO-1
- ❑ use ALARO-1 vs. ALARO-0 difference as an orientation for the magnitude of impact for the namelist variations
- ❑ avoid clustering of members as far as it is possible

The testing was performed on new ALADIN-LAEF 5 km domain (CY40T1_bf6) for the period of the 2 weeks with intense convective cases. For the simplification there was no assimilation cycle used (it is not really necessary for this kind of experiments as only the relative impact is studied). The ALADIN-LAEF system was coupled to ECMWF EPS, where GL tool have been used to produce the ICs and LBCs. The “bad” statistical scores for the surface parameters can be ignored, because just a relative comparison of the scores with respect to the reference (pure downscaling with ALARO-1) is of the interest.

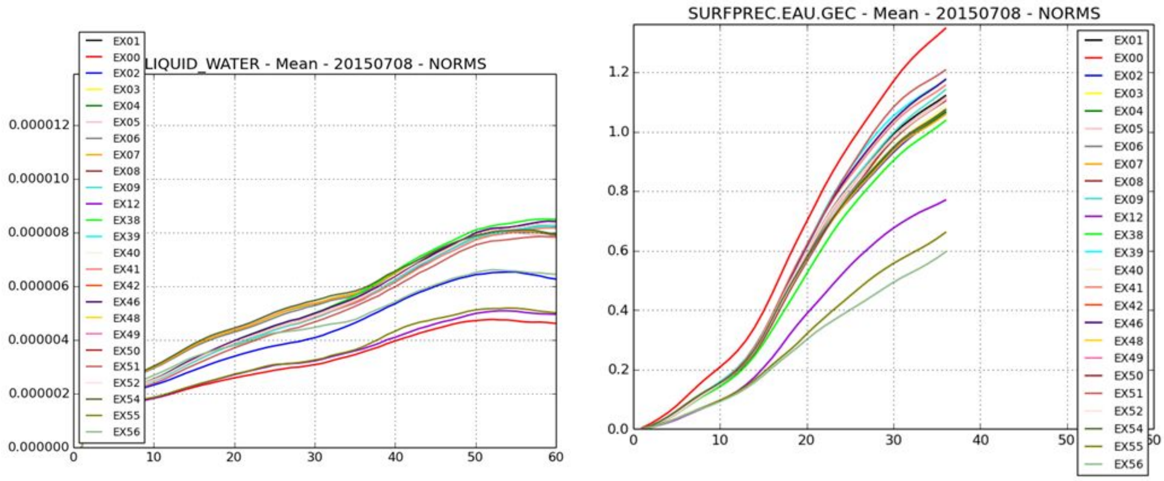


Figure 8: The examples of norms used for the impact tests, where "EX00" is the ALARO-0 reference (red) and "EX01" is the ALARO-1 reference (black), the rest of the experiments are different tested configurations.

For 2 weeks validation period (15 May ~ 01 June, 2016) 6 versions were tested consisting of different combinations of the above experiments. For demonstration, the setup of versions 4 and 5 is shown in the Table 1.

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

Table 1: The construction of multiphysics versions 4 (left) and 5 (right).

The main focus of the individual settings (namelists) for the above configurations is following:

- EXP 57 – ALARO-1 modified turbulence
- EXP 01 – ALARO-1 reference
- EXP 55 – ALARO-1 modified microphysics + deep convection
- EXP 58 – ALARO-1 modified turbulence, microphysics and deep convection
- EXP 00 – ALARO-0 reference

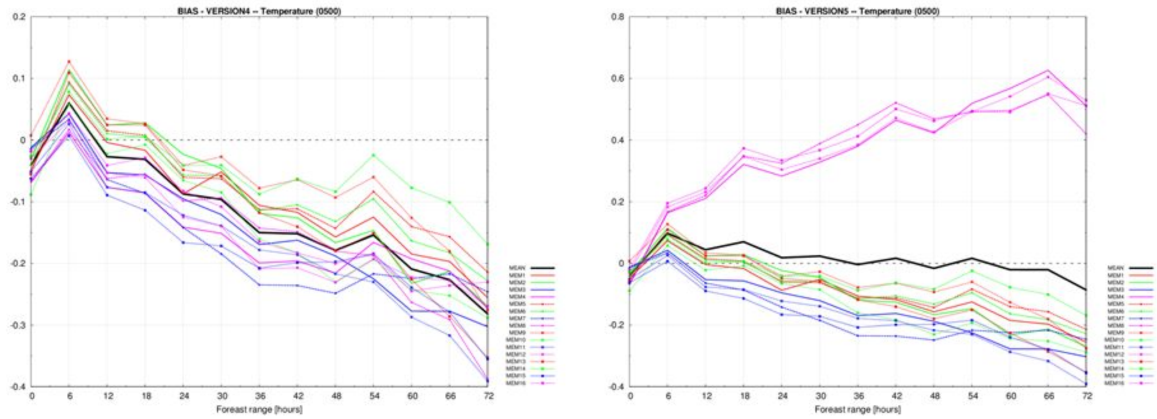


Figure 9: Temperature BIAS at 500 hPa for the ensemble version 4 (left) and version 5 (right).

From the Figure 9 it is obvious, that the version 5 (left) is pretty spoiled by the clustering. Very distinct are the members of ALARO-0 reference (pink). That means, the inclusion of ALARO-0 configuration within the multiphysics setup is not desirable (and will be excluded). On the other hand, the spread for version 4 is much better. The additional experiments with applied SPPT on top of version 4 have shown slight enhancement of the outlier scores, but the overall impact of SPPT seems to be rather small.

Efforts: 11 PM (5 PM LACE stays)

Contributors: Martin Belluš (SHMU), Alena Trojáková (CHMU), Simona Taşcu (NMA), Christoph Wittmann (ZAMG), Yong Wang (ZAMG), Endi Keresturi (PhD at ZAMG)

Documentation: Reports on stays; scientific papers submitted or in the preparation phase

Status: Ongoing

S2 Action/Subject/Deliverable: ALADIN-LAEF maintenance

Description and objectives: 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.

No special tasks nor upgrades of the system were scheduled for this year. Hence, the technical details of ALADIN-LAEF operational version running on CRAY HPCF at ECMWF are without the significant changes:

- 10.9 km horizontal resolution and 45 vertical levels
- 00 and 12 UTC runs up to +72h
- 16 perturbed members + 1 unperturbed control run

- ❑ lagged (by 12h) ECMWF-EPS coupling (first 16 ECMWF-EPS members are used)
- ❑ multi-physics (16 different MP combinations and tunings for micro-physics, deep/shallow convection, radiation and turbulence)
- ❑ ensemble of surface DA by CANARI with perturbed T2m and RH2m observations for the soil and surface IC perturbations
- ❑ upper-air spectral blending by DFI to combine ECMWF-EPS perturbations with ALADIN-LAEF breeding vector for IC perturbations on model levels
- ❑ production and dissemination of multi-GRIB files with the ensemble forecast

Efforts: 0.5 PM

Contributors: Florian Weidle (ZAMG)

Documentation: LAEF flow charts

Status: Permanent maintenance tasks

S3 Action/Subject/Deliverable: AROME-EPS

Description and objectives: 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.

- ❑ **Developments at OMSZ related to ensemble systems:**

At OMSZ they are primarily focusing on their future convection-permitting EPS. However, it was decided to make some final development on the current ALARO-EPS 8 km version. ALARO-EPS 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

After the extension of ECMWF's BC project, ENS BCs became available also for OMSZ. They started to test the impact on these BCs on their ALARO-EPS and compare its performance with the operational one which is coupled to PEARP. With ENS BCs the single members had better quality and the RMSE of the system was favorable but there was also a slight decrease on the ensemble spread. Neither ALARO-EPS coupled to ENS nor ALARO-EPS driven by PEARP were able to outperform ENS itself in terms of the scores but their benefit can be demonstrated on some case studies. All the results are presented in the article published in ECMWF Newsletter No. 148 (Summer 2016 edition).

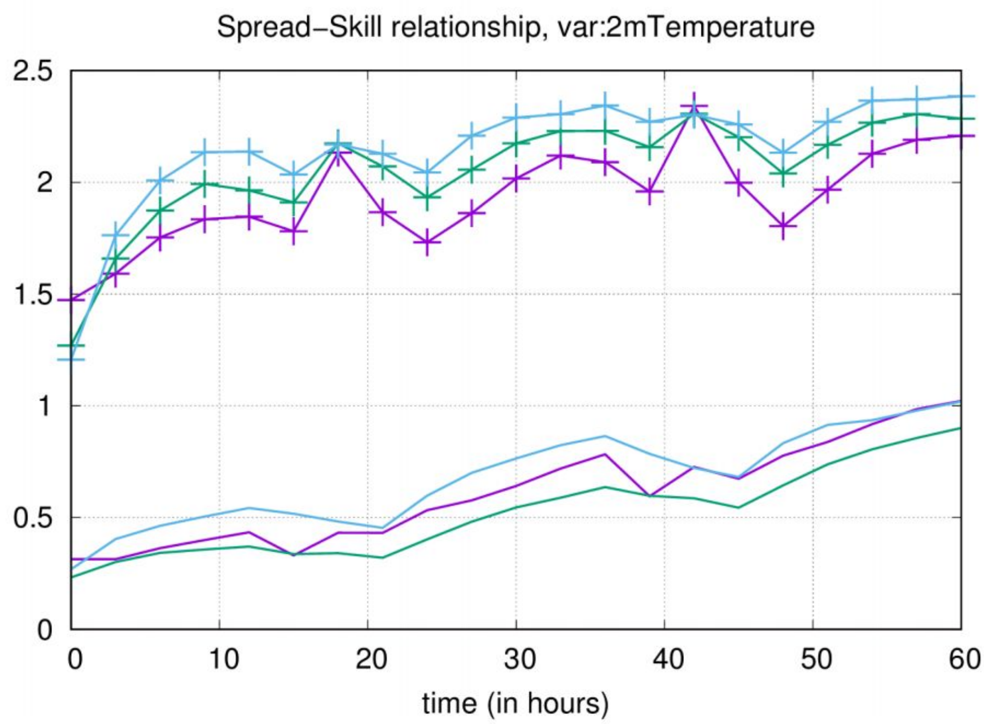


Figure 10: Spread-skill relationship of T2m temperature. ENS with 11 members (purple), ENS coupled ALARO-EPS (green), PEARP coupled ALARO-EPS (blue). Verification period: 11 December, 2015 - 31 January, 2016.

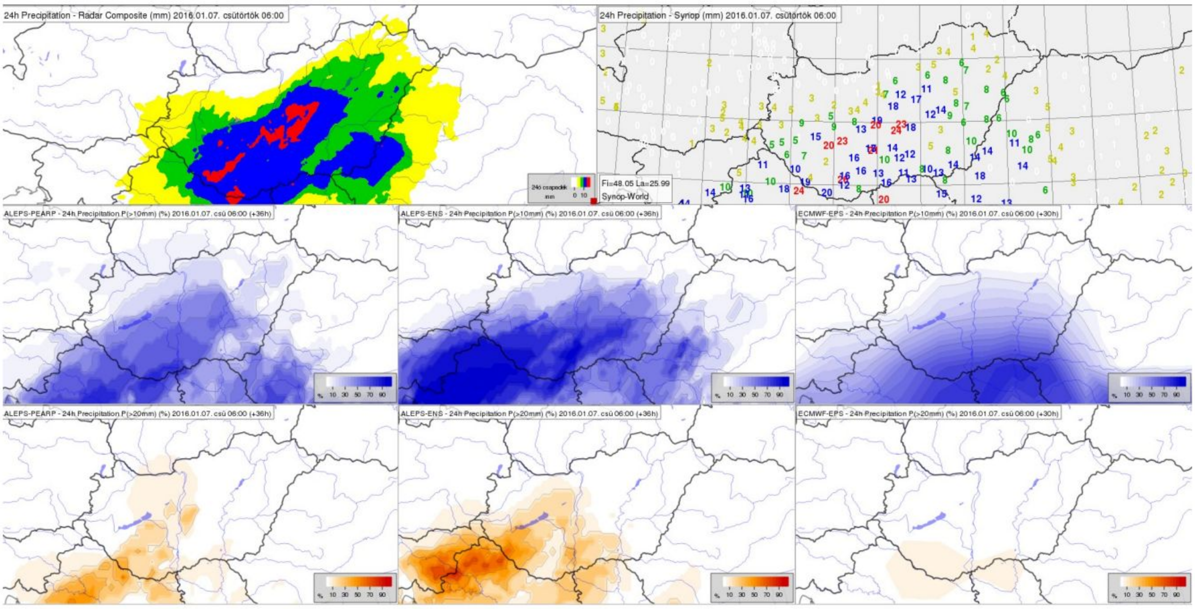


Figure 11: 24-hour precipitation amount at 06 UTC of January 07, 2014. Upper line: radar measurement based estimation (left) and SYNOP observations (right). The corresponding ensemble derived probabilities for 10 mm (middle row) and 20 mm (bottom row) thresholds. Models are (from left to right) the PEARP coupled ALARO-EPS, the ENS coupled ALARO-EPS and the ENS with 10 members.

- Ensemble data assimilation

With the new ENS coupling possibility at OMSZ the EDA system was tested again in ALARO-EPS framework. Similar to the previous tests when EDA was examined in a PEARP coupled version it was found that DA can not ensure the adequate quality even for the control member. This problem has been investigated and it has been found that the source is in the assimilation of satellite data. But the same problem also exists in the 'deterministic' ALADIN runs at OMSZ. It must be solved in the first place, otherwise no other progress in EDA would be possible.

- Stochastic perturbation of physics tendencies

The SPPT development by Mihály Szűcs (LACE stay report, 2015) has been tested. The experiments took place in AROME-EPS framework on CCA cluster at ECMWF. The main goal was to demonstrate that: a) Stochastic pattern generator does not work properly and at least the tuning of its namelist settings is necessary; b) '4D' and '4D elliptic' versions of SPPT have a potential (where the different random numbers are used to perturb each prognostic variable). The results were presented on ALADIN-HIRLAM Workshop in Lisbon.

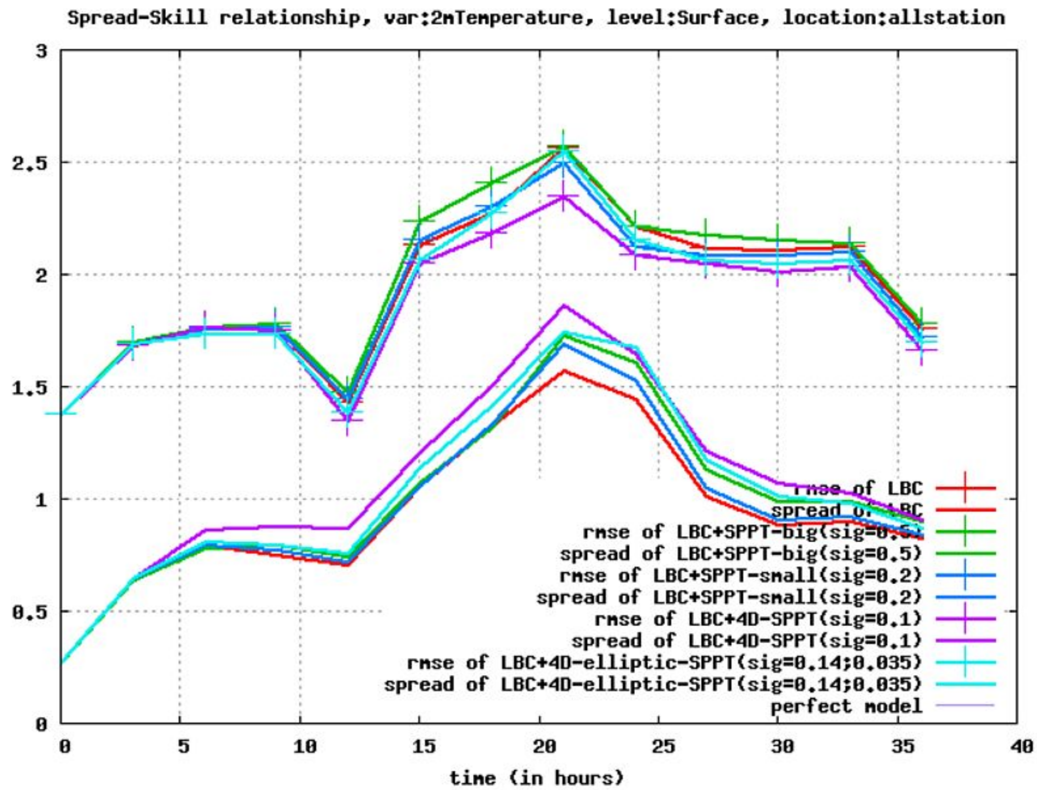


Figure 12: Spread-skill relationship of different SPPT realizations in AROME-EPS framework. Original version without tuning (green) and carefully-revised settings (blue). '4D' (purple) and '4D-elliptic' versions are also compared with the simple downscaling of PEARP (red).

- **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

Several experiments related to the model perturbation by stochastic physics were performed using the above setup:

- SPPT – total tendencies: optimization of stochastic pattern for AROME Austria domain (together with Mihály Szűcs) – debugging (error in pattern generation, pattern was not reproducible with certain settings)

Default setting of Meteo-France is not suitable for AROME Austria domain (u-shaped distribution of generated random numbers). It causes big BIAS and RMSE and the effect of SPPT is generally small.

- partial tendencies (perturbing shallow convection, turbulence and microphysics separately)

There are hardly any differences between the total and partial tendencies concerning the statistical scores. But the model is more stable when the partial tendencies are used (switching off tapering is only possible with partial tendencies).

- influence of tapering function

Significant influence of tapering function in PBL was observed (see Fig. 10). Switching off tapering reduces BIAS and increases SPREAD at 2m, but model becomes unstable in case of the total tendencies.

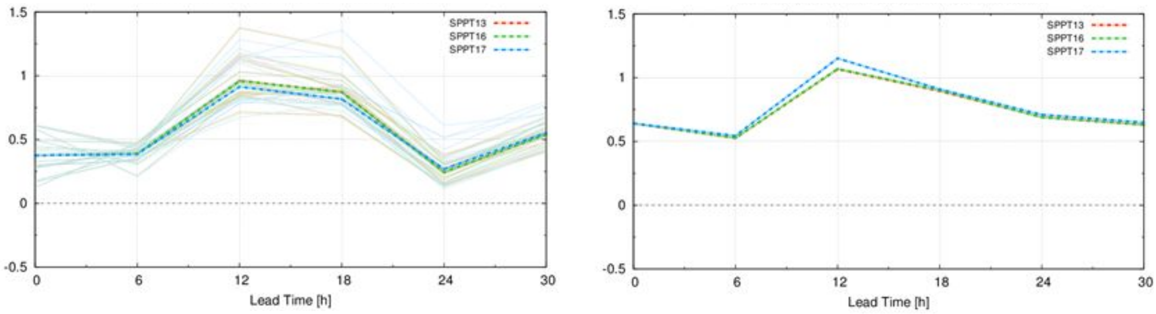


Figure 13: Temperature at 2m BIAS (left) and ensemble SPREAD (right) for the tapering function sensitivity experiments. Partial tendencies with tapering in PBL and stratosphere switched on (red), tapering only in PBL (green) and with the tapering function switch off completely (blue).

In the other experiments it was tested also the influence of seeding, influence of the size of perturbation and the independent partial tendencies with the different stochastic patterns used for shallow convection, turbulence and microphysics.

- **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.

Theoretically, the pattern generator used in SPPT scheme produces Gaussian distributed numbers, where standard deviation (σ) can be controlled from the namelist, as well as the horizontal (L) and temporal (τ) correlation of the random numbers. This kind of random number generation was extended to limited area models in accordance with the different model geometry (Bouttier et al., 2012). In a LACE stay report (Szűcs, 2015) it was already underlined that from the above-mentioned three important control parameters at least two can not work exactly as expected.

The following figure (Fig. 14 on the left side) demonstrates two problematic issues: a) horizontal correlation is smaller than expected, and b) there are too many spots where random numbers have discrete values +1 or -1. The second issue can be also visualized by a histogram of the pointwise values (Fig. 15: on the right side - purple line). Due to the clipping ratio (X=2 as a default) there are no numbers bigger than +1 or smaller than -1. Such clipping procedure bounds the random values into the [-(X*σ);+(X*σ)] interval. As a result, the real standard deviation is much bigger than σ (defined via namelist) and the distribution of the random numbers looks quite strange after the additional clipping.

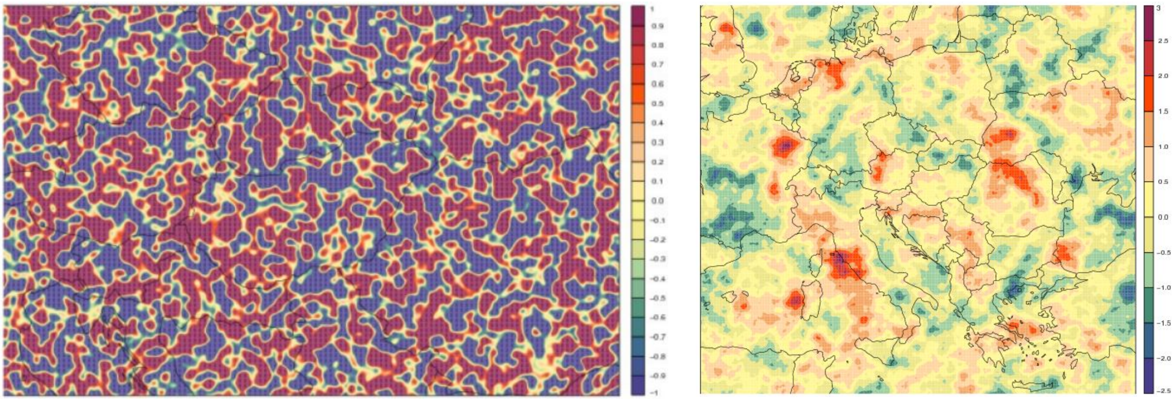


Figure 14: Spectral pattern in AROME model with the original spectral pattern generator (σ=0.5 and L=500km) - left, and random field generated by SPG (as an external program) with the LACE domain specific configuration - right.

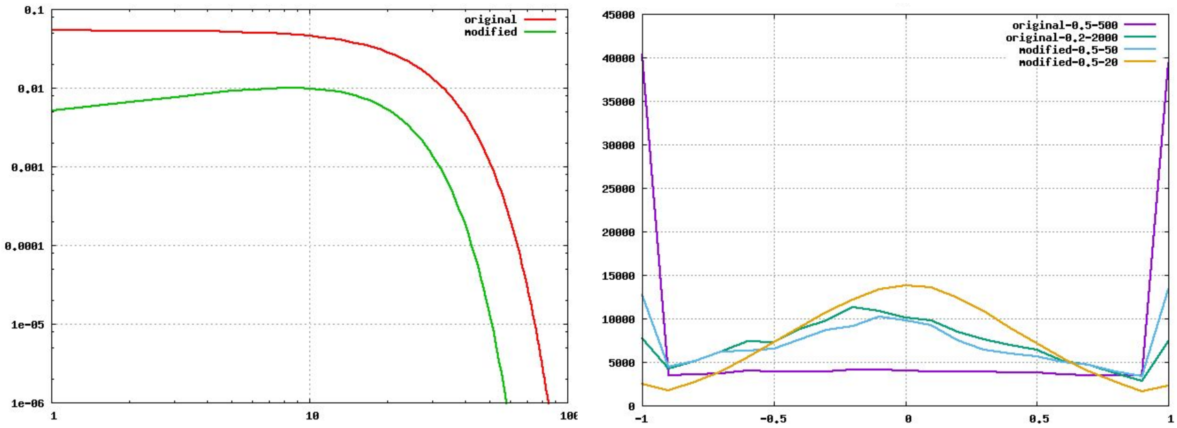


Figure 15: Variance spectrum of random pattern made by current export version (red) and modified version (green) - left, and histogram of random numbers for current export version with default values (purple), with revised setting (green) compared to the modified version with very-long horizontal correlation length (blue) and moderate horizontal correlation length (orange) - right.

To tackle the above mentioned issues, there were two actions. Firstly the current spectral random number generator was modified and secondly a new approach was tested, where different method to obtain random numbers has been implemented.

After the revision of current scheme, some slight but important differences have been discovered in the equations used to define the variance spectrum (in comparison with the original ideas of Weaver and Courtier, 2001). The source of these differences is not clear at the moment. Fig. 15 (left) shows the variance spectrum according to the current equations (red) and modified equations (green) which is identical with the one of Weaver and Courtier, 2001.

A modification of the current version of the code helped to better define the variance spectrum in the setup. This way it is possible to get more reasonable histogram of the random numbers (Fig. 15 - right, blue and orange lines, while green line represents the code without the modifications but with the additional tuning).

In parallel, a new stochastic pattern generator (SPG) implementation has been started, following the work of Michael Tsyrulnikov and Dmitry Gayfulin (Tsyrulnikov and Gayfulin, 2016). There are some attractive properties of SPG. Its basic solver is also spectral-space based, it is developed for the limited area models and 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 (see Fig. 14 - right).

Efforts: 10 PM (1 PM LACE stays)

Contributors: Mihály Szűcs (OMSZ), Clemens Wastl, Christoph Wittmann (both ZAMG)

Documentation: Reports on stays; papers for publication in scientific journals

Status: Ongoing

S4 Action/Subject/Deliverable: EPS - Verification

Description and objectives: A robust and reliable verification tool is very important in order to establish the quality of a weather forecast system, either deterministic or probabilistic one. Knowing the statistical scores and limits of our forecasting system, is the key to future improvements. The huge amount of data are processed from one or more ensemble systems (experiments), which requires an appropriate, optimized and flexible verification tool. That is essential to assess and manipulate such big data volumes.

Efforts: 0.5 PM

Contributors: Simona Taşcu (NMA), Martin Suklitsch (ZAMG)

Documentation: -

Status: Ongoing

S5 Action/Subject/Deliverable: Collaborations

Description and objectives: Activities merging different areas, collaboration with other consortia, applications, projects.

In the framework of the SRNWP-EPS phase II project of EUMETNET a workshop has been organized on “Probabilistic prediction of severe weather phenomena” in Bologna (Italy), hosted by Arpae – SIMC (Hydro Meteo Climate Service), from 17 to 19 of May 2016. The workshop brought together the project participants and scientists working in the field who presented and discussed the current knowledge about the probabilistic prediction of severe weather events, focusing on fog and thunderstorms. Among the other interesting talks a presentation entitled “The convection-permitting ensemble system of the Hungarian Meteorological Service” was given by Mihály Szűcs (OMSZ). During the meeting discussion it was decided that each project participant will identify one or two test periods including cases of significant thunderstorm and fog events. These periods and cases can be different for each NMSs, but they should include similar phenomena. Each NMS will then test the impact of their own perturbation methods using their own ensemble system. The lists of case studies, tested perturbation methods and relevant results will be exchanged among the project participants. A progress discussion will take place beside the EWGLAM meeting in Rome, Italy.

Furthermore, some collaboration with the HIRLAM EPS group has been already started. We are exchanging our scientific plans and the ideas. We agreed on a closer cooperation regarding the topics where both sides can profit from each-other. These are especially the expertise on the model uncertainty simulation. The simplified ALADIN-LAEF multi-physics setup was already tested in the HARMON EPS framework.

Efforts: 2 PM

Contributors: Martin Belluš (SHMU), Mihály Szűcs (OMSZ), Christoph Wittmann (ZAMG)

Documentation: -

Status: Ongoing

S6 Action/Subject/Deliverable: Publications

Description and objectives: The scientific achievements of the LACE EPS R&D activities are being presented at the international workshops and published in the scientific journals. A big effort is put into the publication of interesting scientific results, which is usually a long distance running and time consuming activity, but indeed necessary. In the following we provide an overview of published papers.

- Belluš M., Y. Wang, F. Meier, 2016: “Perturbing surface initial conditions in a regional ensemble prediction system”, Monthly Weather Review, 144 (9), pp 3377–3390, DOI: http://dx.doi.org/10.1175/MWR-D-16-0038.1

Abstract. Two techniques for perturbing surface initial conditions in the regional ensemble system Aire Limitée Adaptation Dynamique Développement International-Limited Area Ensemble Forecasting (ALADIN-LAEF) are presented and investigated in this paper. The first technique is the noncycling surface breeding (NCSB), which combines short-range surface forecasts driven by perturbed atmospheric forcing and the breeding method for generating the perturbations on surface initial conditions. The second technique, which is currently used in the ALADIN-LAEF operational version, applies an ensemble of surface data assimilations (ESDA) in which the observations are randomly perturbed. Both techniques are evaluated over a two-month period from late spring to summer. The results show that the evaluation is more favorable to ESDA. In general, the ensemble forecasts of the observed near-surface meteorological variables (screen-level variables) of ESDA are more skillful than NCSB, in particular for 2-m temperature they are statistically more consistent and reliable. A slightly better statistical reliability for 2-m relative humidity and 10-m wind has been found as well. This could be attributed to the introduction of surface data assimilation in ESDA, which provides more accurate surface initial conditions. Moreover, the observation perturbation in ESDA helps to better estimate the initial condition uncertainties. For the forecast of precipitation and the upper-air variables in the lower troposphere, both ESDA and NCSB perform very similarly, having neutral impact.

- 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

Abstract. The 2.5 km convection-permitting (CP) ensemble AROME-EPS (Applications of Research to Operations at Mesoscale – Ensemble Prediction System) is evaluated by comparison with the regional 11 km ensemble ALADIN-LAEF (Aire Limitée Adaptation dynamique Développement InterNational – Limited Area Ensemble Forecasting) to show whether a benefit is provided by a CP EPS. The evaluation focuses on the abilities of the ensembles to quantitatively predict precipitation during a 3-month convective summer period over areas consisting of mountains and lowlands. The statistical verification uses surface observations and 1 km × 1 km precipitation analyses, and the verification scores involve state-of-the-art statistical measures for deterministic and probabilistic forecasts as well as novel spatial verification methods. The results show that the convection-permitting ensemble with higher resolution AROME-EPS outperforms its mesoscale counterpart ALADIN-LAEF for precipitation forecasts. The positive impact is larger for the mountainous areas than for the lowlands. In particular, the diurnal precipitation cycle is improved in AROME-EPS, which leads to a significant improvement of scores at the concerned times of day (up to approximately one third of the scored verification measure). Moreover, there are advantages for higher precipitation thresholds at small spatial scales, which is due to the improved simulation of the spatial structure of precipitation.

- Szűcs M., P. Sepsi, A. Simon, 2016: "Hungary's use of ECMWF ensemble boundary conditions", ECMWF Newsletter No. 148 – Summer 2016, pp 24-30

The whole ECMWF Newsletter No. 148 - Summer 2016 can be downloaded in PDF: http://www.ecmwf.int/sites/default/files/elibrary/2016/16523-newsletter-no148-summer-2016.pdf

- Szűcs M., A. Horányi, G. Szépszó, 2016: "Ensemble Methods in Meteorological Modelling", In: Bátkai A., Csomós P., Faragó I., Horányi A., Szépszó G. (eds) Mathematical Problems in Meteorological Modelling. Mathematics in Industry, Vol 24, pp 207-237. Springer. DOI: 10.1007/978-3-319-40157-7_11

Abstract. Numerical modelling is a continuously developing discipline in meteorology, which provides meteorological forecasts and climate change projections based on the numerical solutions of the set of equations describing the processes in the atmosphere and the related spheres. The progress in numerical weather prediction (NWP) and climate modelling has been enormous in the last few decades thanks to the improved theoretical understanding of the meteorological processes, the growing number of observations and the increasing available computer power. In spite of the steady progress, meteorological forecasts cannot be fully perfect due to the intrinsic characteristics of the atmosphere and the climate system. Weather forecast uncertainties exist in initial conditions and in the model formulations themselves and evolve rapidly with lead time. In climate change projections the initial conditions have negligible role, but the internal climate variability and the unknown future evolution of the anthropogenic activity are additional sources of uncertainties. Since they cannot be avoided (just minimized), their representation and quantification are essential tasks both in numerical weather prediction and climate research. Currently the only feasible way to challenge this problem is the ensemble approach, which delivers probabilistic information and attributes uncertainty information to the numerical weather forecasts and climate projections. This additional uncertainty estimation is a valuable bonus for the users and can be efficiently applied in decision-making.

Unfortunately, due to the lack of manpower some of the other long-term planned papers must have been postponed again. That is the document which should deal with the different approaches to boundary condition interpolation, i.e. spatio-temporal consistency and its hypothetical exploitation as a generator of the targeted initial perturbations. Postponed was also the paper about the model uncertainty simulation by the stochastic perturbation of physics tendencies for the surface prognostic variables in ALADIN-LAEF system.

Efforts: 6 PM

Contributors: Yong Wang, Theresa Schellander-Gorgas, Florian Weidle, Alexander Kann, Christoph Wittmann, Florian Meier (all ZAMG), Martin Belluš (SHMU), Mihály Szűcs (OMSZ)

Documentation: Reviewed papers

Status: Ongoing

List of actions, deliverables including status

S1 Subject: Optimization of ALADIN-LAEF

Deliverables: Reports on LACE stays; papers submitted to scientific journals; improvement of current regional ensemble system through the results and outcomes of R&D

Status: In progress

S2 Subject: ALADIN-LAEF maintenance

Deliverables: ALADIN-LAEF operational suite running at ECMWF HPC; probabilistic forecast products delivered to the LACE partners

Status: Permanent

S3 Subject: AROME-EPS

Deliverables: Reports on LACE stays; papers submitted to scientific journals; convection-permitted ensemble system prototypes for preoperational or operational use

Status: In progress

S4 Subject: EPS - Verification

Deliverables: Upgrades of LAEF Verification package; bug-fixes

Status: Ongoing

S5 Subject: Collaborations

Deliverables: Exchange of the expertise between the other consortia or within the relevant projects

Status: Ongoing

S6 Subject: Publications

Deliverables: 4 papers published and 2 papers in preparation (see list of publications below)

Status: Ongoing

Documents and publications

Published papers:

❑ Belluš M., Y. Wang, F. Meier, 2016: "Perturbing surface initial conditions in a regional ensemble prediction system", Monthly Weather Review, 144 (9), pp 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, pp 24-30, http://www.ecmwf.int/sites/default/files/elibrary/2016/16523-newsletter-no148-summer-2016.pdf

- Szűcs M., A. Horányi, G. Szépszó, 2016: "Ensemble Methods in Meteorological Modelling", In: Bátkai A., Csomós P., Faragó I., Horányi A., Szépszó G. (eds) Mathematical Problems in Meteorological Modelling. Mathematics in Industry, Vol. 24, pp 207-237. Springer. DOI: 10.1007/978-3-319-40157-7_11

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

Stay reports:

- Alena Trojáková, 2016: IC perturbations by 3DVAR in ALADIN-LAEF, Report on stay at ZAMG, 25/04~20/05, 2016, Vienna, Austria
- Martin Belluš, 2016: New high resolution ALADIN-LAEF on CY40T1 with ALARO-1 physics, Report on stay at ZAMG, 25/04~13/05 + 06/06~10/06, 2016, Vienna, Austria
- Simona Taşcu, 2016: Optimization of ALADIN-LAEF at 5 km horizontal resolution, Report on stay at ZAMG, 04/07~26/08, 2016, Vienna, Austria (in preparation)
- Mihály Szűcs, 2016: Stochastic pattern generators, Report on stay at ZAMG, 23/05~17/06, 2016, Vienna, Austria
- Martin Belluš, 2016: Spectral blending on high resolution issue, Report on stay at ZAMG, 24/10~18/11, 2016, Vienna, Austria

Activities of management, coordination and communication

- 26th ALADIN Workshop & HIRLAM All Staff Meeting 2016, 4-8 April 2016, Lisbon, Portugal (oral presentations of Martin Belluš, Mihály Szűcs).
- SRNWP-EPS II Project Workshop, 17-19 May 2016, Bologna, Italy (participation of Martin Belluš, oral presentation of Mihály Szűcs).
- 38th EWGLAM/23rd SRNWP joined meetings, 3-6 October 2016, Rome, Italy (oral presentations of Martin Belluš, Yong Wang).

- HIRLAM Working Week on EPS and Predictability, 21-25 November 2016, Helsinki, Finland (participation of Mihály Szűcs, paid by HIRLAM)

LACE supported stays – 6 PM in 2016

There were five stays executed in 2016:

- Martin Belluš [**S1**], 25 Apr ~ 13 May + 6 ~ 10 Jun 2016, ZAMG (4 weeks)
- Alena Trojáková [**S1**], 25 Apr ~ 20 May 2016, ZAMG (4 weeks)
- Simona Taşcu [**S1**], 4 Jul ~ 26 Aug 2016, ZAMG (8 weeks)
- Mihály Szűcs [**S3**], 23 May ~ 17 Jun 2016, ZAMG (4 weeks)
- Martin Belluš [**S1**], 24 Oct ~ 18 Nov 2016, ZAMG (4 weeks)

Summary of resources [PM]

Subject	Manpower		LACE		ALADIN	
	plan	realized	plan	realized	plan	realized
S1: Optimization of LAEF	10	11	5	5		
S2: LAEF maintenance	1	0.5				
S3: AROME-EPS	10	10	1	1		
S4: EPS – Verification	1	0.5				
S5: Collaborations	2	2				
S6: Publications	6	6				
Total:	30	30	6	6	0	0