Working Area Predictability

Progress Report

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Period:	2017 (final)
Date:	March 2018

Progress summary

The work on ALADIN-LAEF system upgrade towards the higher resolution continued slowly but steadily also in 2017. All experiments were already executed on new computational domain, using new code (cy40t1) with many bugfixes. These were especially the quadratic coupling interpolation issue and the conversion/interpolation of SST/LST fields in the initial conditions, which were identified and successfully fixed during the development.

In 2017 there were seven RC LACE stays executed by Predictability working group, all of them were hosted by ZAMG. Martin Dian (SHMU) spent 4 weeks investigating the supersaturation problem when the stochastic perturbation methods are used in EPS. Martin Belluš (SHMU) spent twice 4 weeks a) implementing surface IC and model perturbation techniques into the new version of ALADIN-LAEF and b) building/testing its phase I configuration meant for the operations at ECMWF HPCF. Mihály Szűcs (OMSZ) spent 6 weeks with the implementation of new spectral pattern generator (SPG) by Tsyrulnikov-Gayfulin in the ALADIN code. Simona Taşcu (NMA) came to Vienna only for 1 week to supervise newcomer Raluca Pomaga, who continued on Simona’s last year’s topic. Raluca Pomaga (NMA) spent 4 weeks reviewing new ALADIN-LAEF multiphysics and its combination with the stochastic perturbation of physics tendencies. Iris Odak Plenković (DHMZ) spent 4 weeks working on the analog-based post-processing method for the wind field.

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.

- **Topic 1: Supersaturation problem in models with SPPT**

The Stochastic Perturbation of Physics Tendencies (SPPT) systematically reduces humidity in the model atmosphere. The reason being the perturbation of specific humidity and/or temperature, which can easily push model into the "supersaturation" state. Due to the irreversible precipitation processes it is cumulatively drying the model atmosphere. Some tests were originally performed by Mihaly Szűcs (see Szűcs, 2016: “SPPT in AROME and ALARO: test results and open questions”, presentation at HIRLAM WW on EPS and Predictability). He found that also with the different supersaturation check methods within SPPT, the negative bias for humidity and precipitation is still present.

The aim of the work was to investigate the issue separately for the surface and upper-air stochastic perturbation and possibly find the solutions.

- Surface SPPT

A small domain with horizontal resolution 4.8 km and 360 x 288 grid points over Central Europe was used for the experiments. ALADIN-LAEF counting 8 members on cy40t1 with ALARO-1 physics was run at ECMWF's HPCF. The following ISBA tendencies were perturbed in accordance with "Stochastically perturbed physics tendencies of surface fields in ALADIN-LAEF system" (Belluš, 2014, RC LACE Report): surface temperature, liquid soil water content, frozen soil water content, water intercepted by vegetation, snow reservoir water content, snow albedo and snow density.

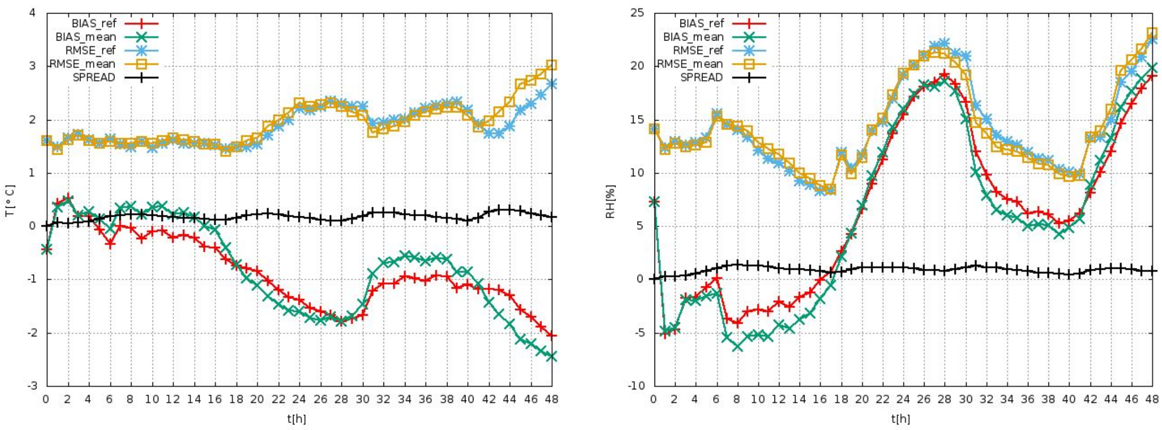

Figure 1: BIAS and RMSE of temperature (left) and relative humidity (right) for May 15, 2011. BIAS and RMSE of deterministic run are denoted by red and blue lines respectively. BIAS and RMSE of the ensemble mean are denoted by green and yellow lines respectively. Hourly measurements from stations below 600 m a.s.l. were used in this verification.

RMSE of the ensemble mean for temperature and relative humidity (yellow lines on Fig.1) correspond very well to the reference deterministic run without the perturbed variables (blue lines on Fig.1) without any significant deviations. Same results are observed for BIAS (red and green lines on Fig.1). It can be concluded that the stochastic perturbation did not create any significant biases in the ensemble when the surface prognostic variables are perturbed.

❑ Upper-air SPPT

The work continued on upper-air SPPT at SHMU HPC, where the code was implemented to cy40t1 with ALARO-1 physics. In order to optimize CPU time usage the same small domain was used, but with coarser resolution (180x144 grid points, 9.6 km). Tests were done with individually switched on/off humidity, temperature and wind components perturbations and with different supersaturation check settings (NQSAT_SDT). On the following figure (Fig.2) the differences between perturbed and unperturbed runs (4 independent cases) for relative humidity at 850 hPa level averaged over the domain are shown. Green lines correspond to NQSAT_SDT=0 (perturbations are canceled when oversaturation is reached). Such case is on average 3% dryer. For NQSAT_SDT=3 (iteratively decreased perturbations if oversaturation is reached) the drying was reduced to about 0.5% (blue line). Even when perturbing only wind and temperature (without specific humidity and with switched off supersaturation check), the drying effect is still present (yellow line). The drying of atmosphere disappeared only when perturbing purely wind components (black line). The same, but for temperature field, is shown on the figure 3.

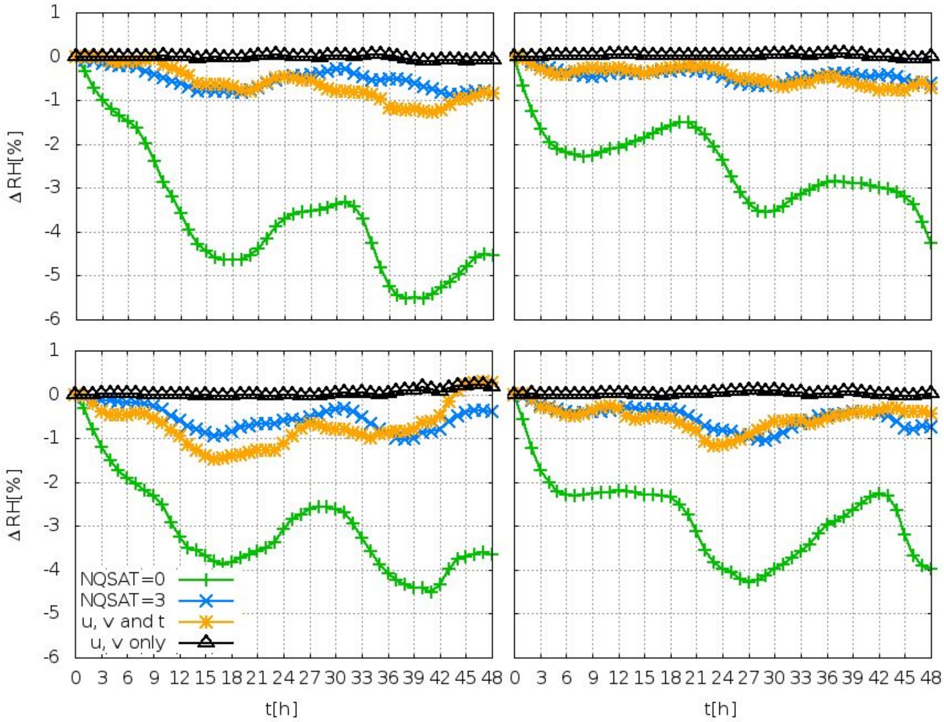

Figure 2: Relative humidity difference between the experiment with SPPT (8 members) and reference deterministic run at 850 hPa for 4 independent cases averaged over the domain.

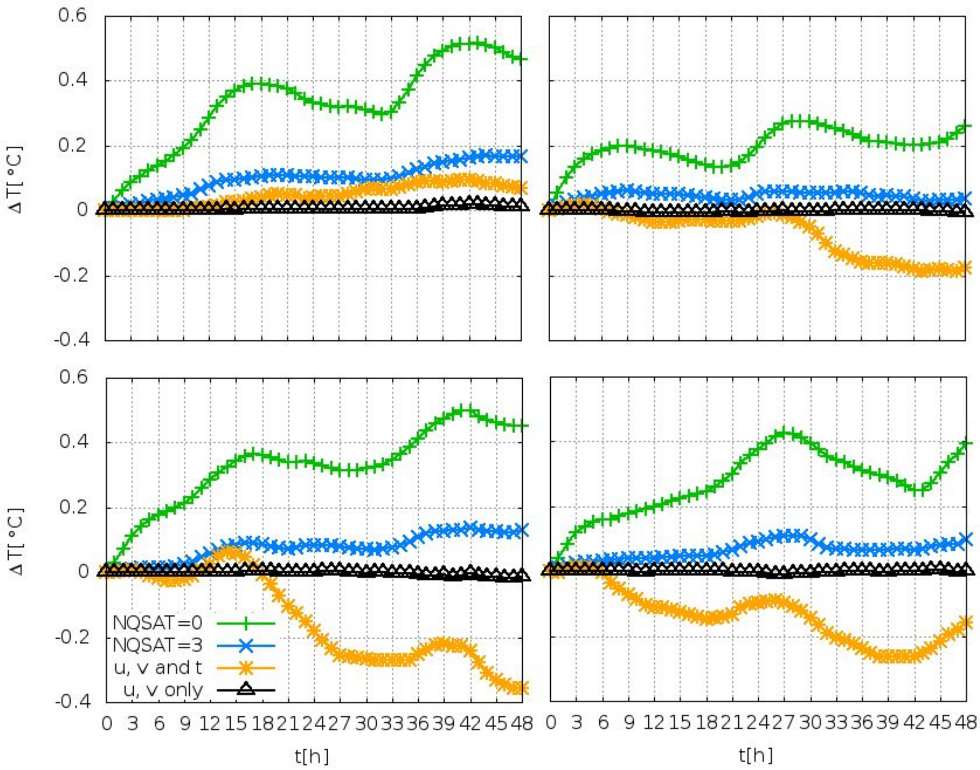

Figure 3: Temperature difference between the experiment with SPPT (8 members) and reference deterministic run at 850 hPa for 4 independent cases averaged over the domain.

❑ Topic 2: IC and model perturbations for new ALADIN-LAEF

The different perturbation methods within the new ALADIN-LAEF system were implemented and tested. The whole system was upgraded to cycle 40t1 with ALARO-1 physics. This was a necessary step towards the operational upgrade of spatial resolution to 5 km with the 60 vertical levels. An Ensemble of Surface Data Assimilation (ESDA) was implemented with the two possible ways how to perturb the observations: a) externally; b) by model configuration - screening. Model perturbation was simulated: a) by stochastic physics (surface SPPT); b) by reduced set of different physics parameterizations using new ALARO-1 package (1 configuration per 4 ensemble members). The impact of each individual method was clearly positive and in accordance with the expectations and theory.

❑ IC perturbation - ESDA

The surface assimilation cycle for new LAEF5 domain using cy40t1 with several known bugfixes for quadratic coupling interpolation, T2m interpolation, surface SPPT development, etc. was implemented. This was rather big code update considering the operational version, which is still running on cy36t1.

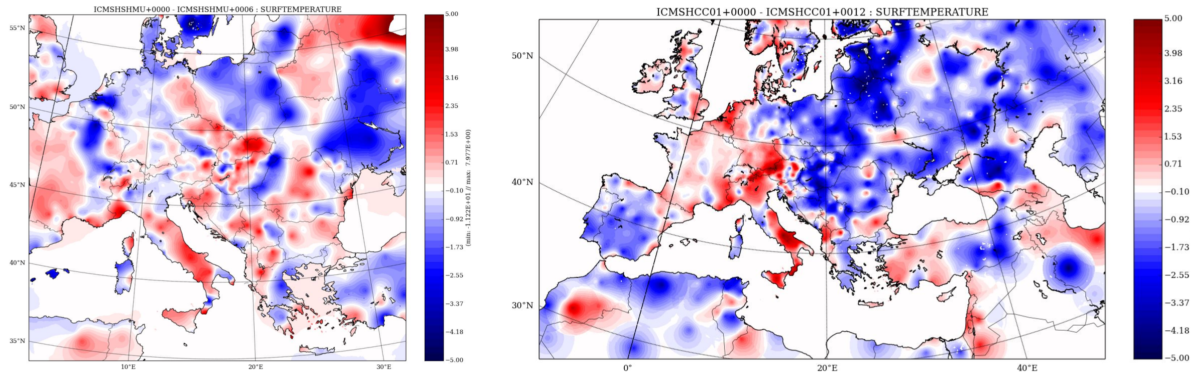

Figure 4: The assimilation increments for surface temperature (analysis - guess) for SHMU oper suite 4.5 km (left) and LAEF 4.8 km (right) - both on the cycle 40t1. The corresponding color scales are equal for direct intercomparison. Note that the analyzed day is different for SHMU and LAEF, and also LAEF assimilation cycle was tested (warmed up) only for one week period.

OBS perturbation - external:
The external tool for OBS perturbation (ECMAPERT by A. Storto) within the ECMA database was updated to cy40t1 ODB changes and compiled via gmkpack.

OBS perturbation - internal:
The new OBS perturbation method has been scripted into the existing CANARI (canari.pl) module of LAEF5. The perturbation is done by model configuration screening (LPERTURB=.T., NAENSEMBLE=1, NAEMEMBER=$mem in &NAMSCC namelist).

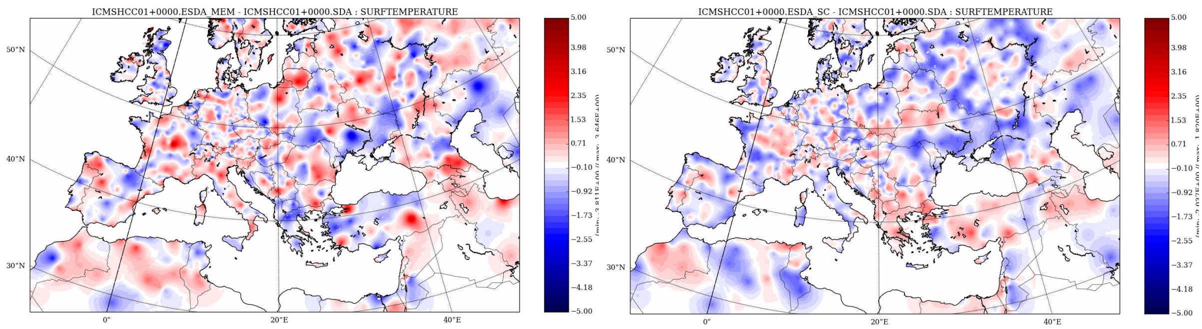

Figure 5: The temperature perturbation at the surface (pertOBS analysis - reference analysis) for LAEF 4.8 km domain on cycle 40t1. There is ensemble member 01 perturbation by external method (left) and by internal method (right) - both initialized with the same SEED number. Deep soil temperature perturbation corresponds very well to this too, with exactly the same structure but by one order of magnitude smaller values (not shown).

Both OBS perturbation methods perform reasonably well. The disadvantage of external one might be in the problematic maintenance and tricky compilation of the external code under the newer model cycles. The internal method has also a potential drawback, we can't perturb the observations just after the quality control as it is the case in current operations (in order to keep all perturbed values involved). Instead, it happens exactly in the opposite order, but shouldn't be necessarily a problem at all. Such approach was tested for the first time in the surface assimilation procedure, when ECMA ODB was manipulated by 3DVar-like screening with the subsequent CANARI surface analysis.

- ❏ Model perturbation - SPPT, multiphysics

Stochastic perturbation of physics tendencies:
The stochastic perturbation is called each time step in grid-point space where surface prognostic fields are perturbed. These are the surface temperature, surface liquid water content, surface frozen water content, snow albedo, snow reservoir water content, snow density and water intercepted by vegetation. Seven fields altogether. The direct perturbation of deep soil prognostic fields (such as deep soil temperature or deep soil moisture) was intentionally avoided because they naturally change slower in time, with some delay with respect to the surface.

Multiphysics:
The reduced set of different parameterizations was tested and compared against the unperturbed run. As for all the other experiments, surface data assimilation was applied in the experiment as well as in the reference. The ensemble members "04, 08, 12, 16" have ALARO-1 recommended settings (i.e. according the export version). While the members in three other groups "01, 05, 09, 13", "02, 06, 10, 14" and "03, 07, 11, 15" differ in some settings related to the microphysics, turbulence and deep convection. These are the ALARO-1 settings recommended by Christoph Wittmann and Simona Tascu, after their many experiments containing much bigger range of different configurations in 2016.

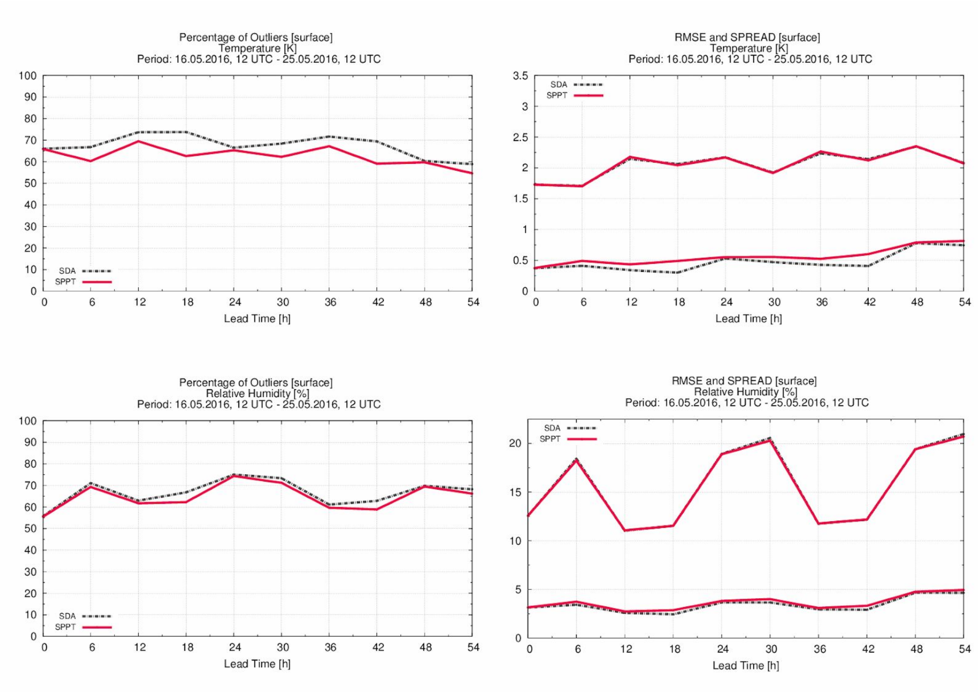

Figure 6: Temperature (up) and relative humidity (bottom) verification for the period of 10 days from 16 to 25 May 2016, 12 UTC run of the full LAEF ensemble (16 members). The percentage of outliers (left) and RMSE of the ensemble mean with ensemble spread (right) are shown for the reference (SDA, black dashed) and stochastically perturbed physics tendencies of surface prognostic fields experiment (SPPT, red).

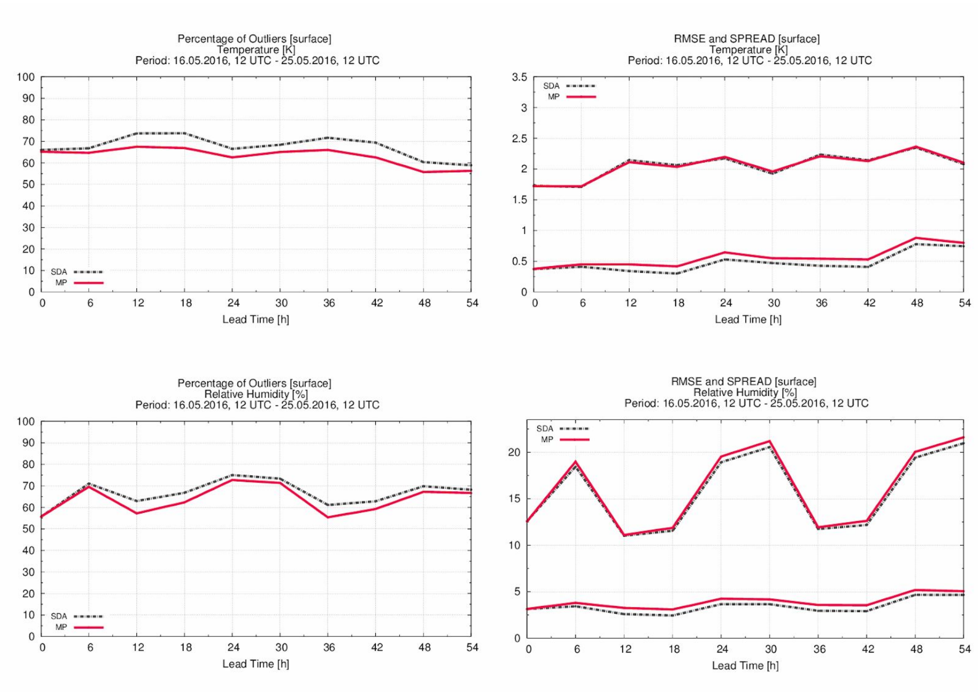

Figure 7: Temperature (up) and relative humidity (bottom) verification for the period of 10 days from 16 to 25 May 2016, 12 UTC run of the full LAEF ensemble (16 members). The percentage of outliers (left) and RMSE of the ensemble mean with ensemble spread (right) are shown for the reference (SDA, black dashed) and multiphysics experiment (MP, red).

- LBC perturbation - coupling

For the operations, the ENS data are still produced at ECMWF also on the original grid (they are upscaled). But one can not fully benefit from the increased grid-point resolution this way. Furthermore, these data are not archived, hence for the research experiments some other tools have to be utilized, like GL. Regardless of GL tool limitations considering the vertical interpolations, we have found another issue. The surface temperature (sea + land) was extracted from provided climatological files instead of the skin (skt) and sea-surface (stt) temperature fields which are available in ECMWF grib files. As a result the SST was not changing within the initial conditions of different model runs for given month! On the other hand, the land-surface temperature was not necessarily a big issue as far as the local assimilation cycle is involved (as it is the case in the above experiments). However, for the dynamical adaptation such boundary conditions are not suitable. (Please, see the Topic 5, where this issue was further examined and successfully solved.)

- **Topic 3: Revision of ALADIN-LAEF multiphysics and its combination with SPPT**

New multiphysics settings were revised in the frame of the bugfixed code of cy40t1, mainly with respect to the correction of quadratic coupling interpolation bug (see Belluš, 2016: “Spectral blending on high resolution issue”, RC LACE Report). The comparison between bf05 and bf07 was carried out for 2 weeks verification period. Only a slight improvement was observed, mostly for geopotential (see Fig.8) and MSLP (not shown).

In the next experiments also stochastic perturbation of physics tendencies (SPPT) was activated (see Fig.9) and supersaturation adjustment was changed (NQSAT_SDT=3 instead of default 0). The latter should have affect the precipitation and humidity BIAS, but the observed differences were not significant.

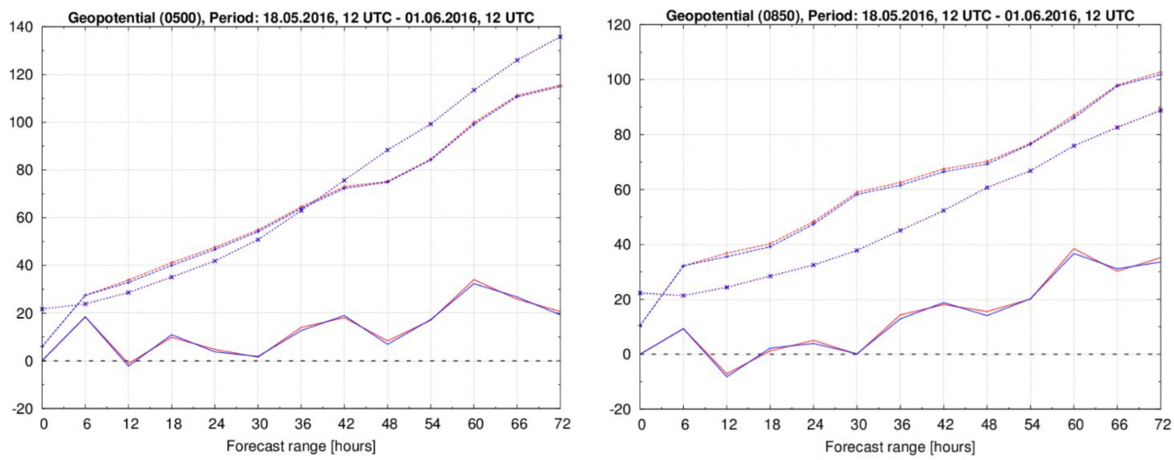

Figure 8: RMSE, BIAS and SPREAD for geopotential at 500 hPa (left) and 850 hPa (right) for the reference (cy40t1_bf05, red lines) and experiment (cy40t1_bf07, blue lines) with new multiphysics.

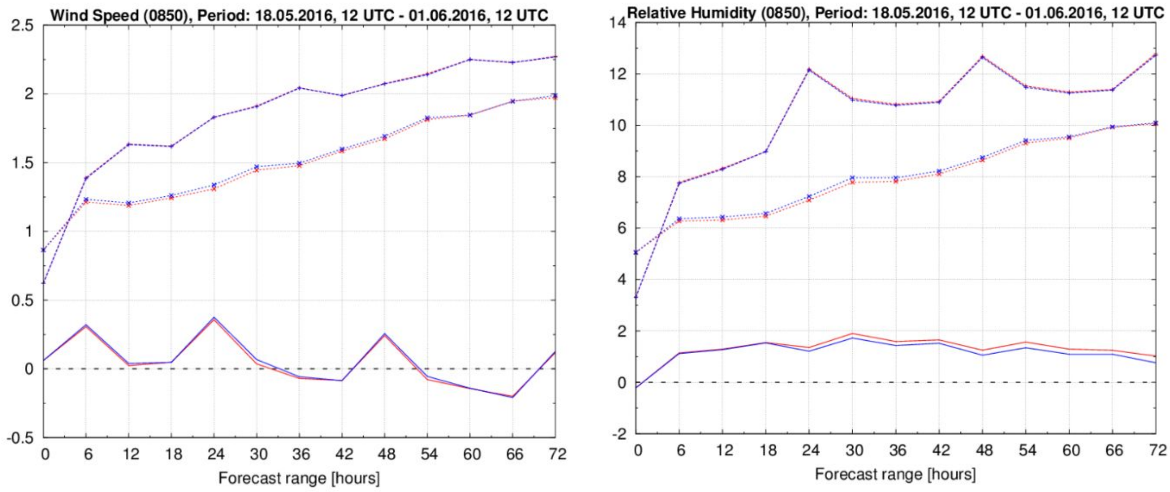

Figure 9: RMSE, BIAS and SPREAD for wind speed (left) and relative humidity (right) at 850 hPa for the reference (cy40t1_bf07 with multiphysics, red lines) and experiment (cy40t1_bf07 with multiphysics+SPPT, blue lines).

Some slight BIAS reduction and SPREAD increase along the neutral impact on RMSE scores can be observed for the experiment with the additional stochastic perturbation (see Fig.9). This applies mostly to relative humidity and wind speed at the upper-air but also near surface. For the other fields the effect is hardly visible.

The impact of different configurations was also analyzed on a local flash flood event when the amount of precipitation exceeded 100 mm in 24 hours in specific areas over Austria (see Fig.10).

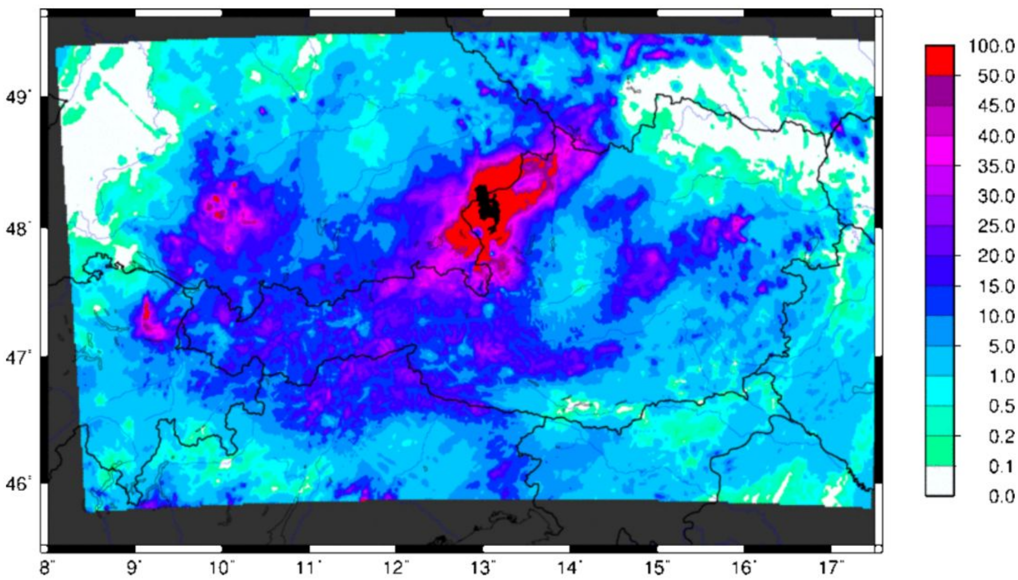

Figure 10: INCA analysis, 24h accumulated precipitation, May 31 - June 01, 2016.

Four experiments were examined: a) multiphysics, b) SPPT, c) multiphysics + SPPT, d) multiphysics + SPPT + NQSAT_SDT=3. Each of them had only four members with different namelists, and they were coupled to the same boundary conditions. For this case only a little increase of precipitation amount with respect to the reference (namelist 01) was observed when multiphysics together with SPPT have been applied (see Fig.11). However, the additional change of supersaturation adjustment (NQSAT_SDT=3) haven't brought any significant modification of precipitation field (not shown).

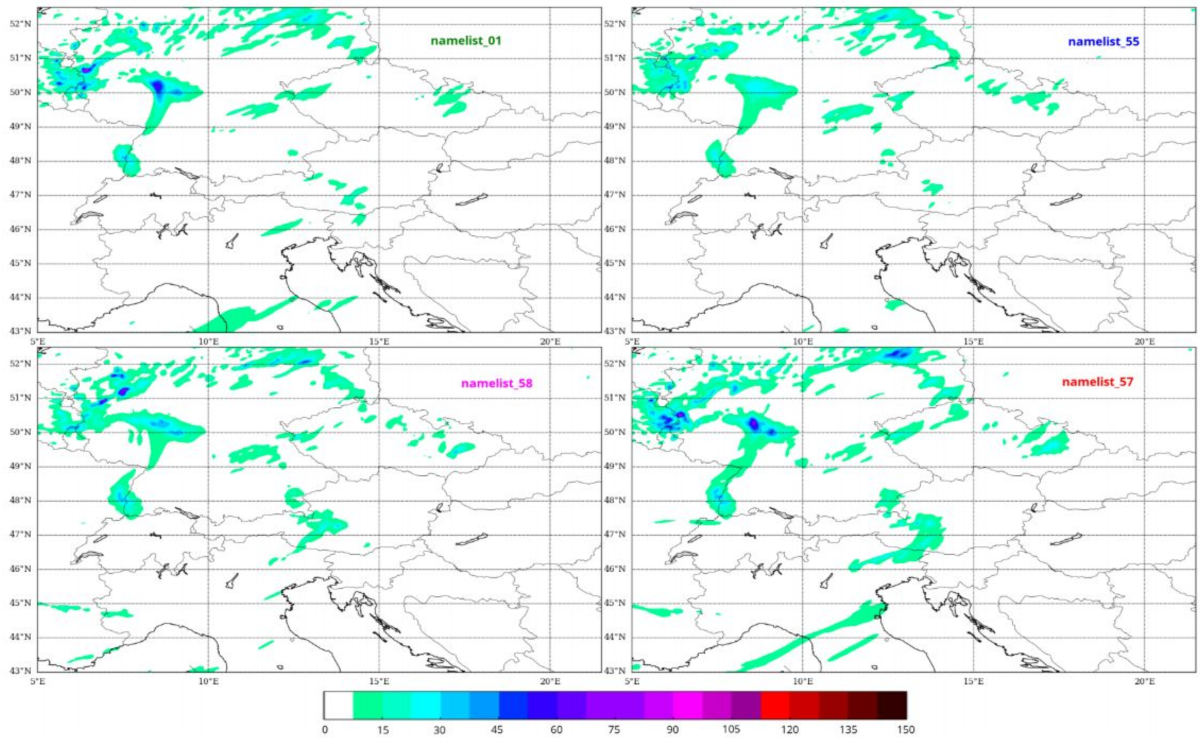

Figure 11: Accumulated precipitation forecast for 24h period (May 31 - June 1, 2016) with ALADIN-LAEF ensemble (4 members equally coupled) with activated multiphysics and SPPT. The reference forecast is shown in the upper-left panel.

- **Topic 4: Jk 3DVar method (Endi's PhD)**

The general idea is similar to the upper-air spectral blending by digital filter but utilizing the different technique. One has to include the global model information directly into the LAM variational assimilation. As a result the combination of large scale (GM-EPS) and small scale (LAM-EPS) perturbation is obtained, which better simulates the uncertainty of the atmosphere on finer spatial resolution. Another benefit of such method(s) being the resulting consistency of generated IC and downscaled global LBC perturbations used in regional or convection-permitting EPS.

In the following equations one can see the difference between standard cost function used in 3DVar (1) and modified cost function with the additional term due to Jk blending method (2), where Jk represents the large scale perturbations.

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

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

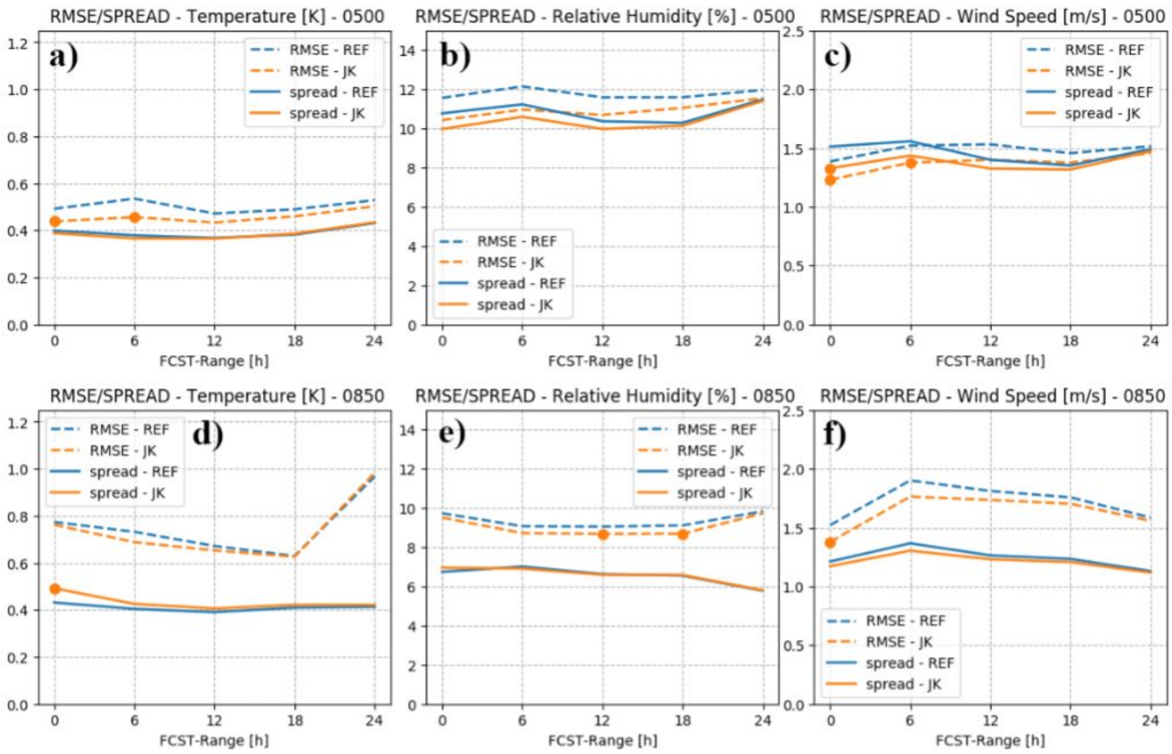

Figure 12: RMSE of ensemble mean (dashed) and ensemble spread (solid) of REF (AROME-EPS with 3DVar without Jk term) - blue and Jk - orange for (a) T500; (b) RH500; (c) W500; (d) T850; (e) RH850 and (f) W850. The verification period is July 2016. Forecast ranges with statistically significant differences are marked with a bullet symbol.

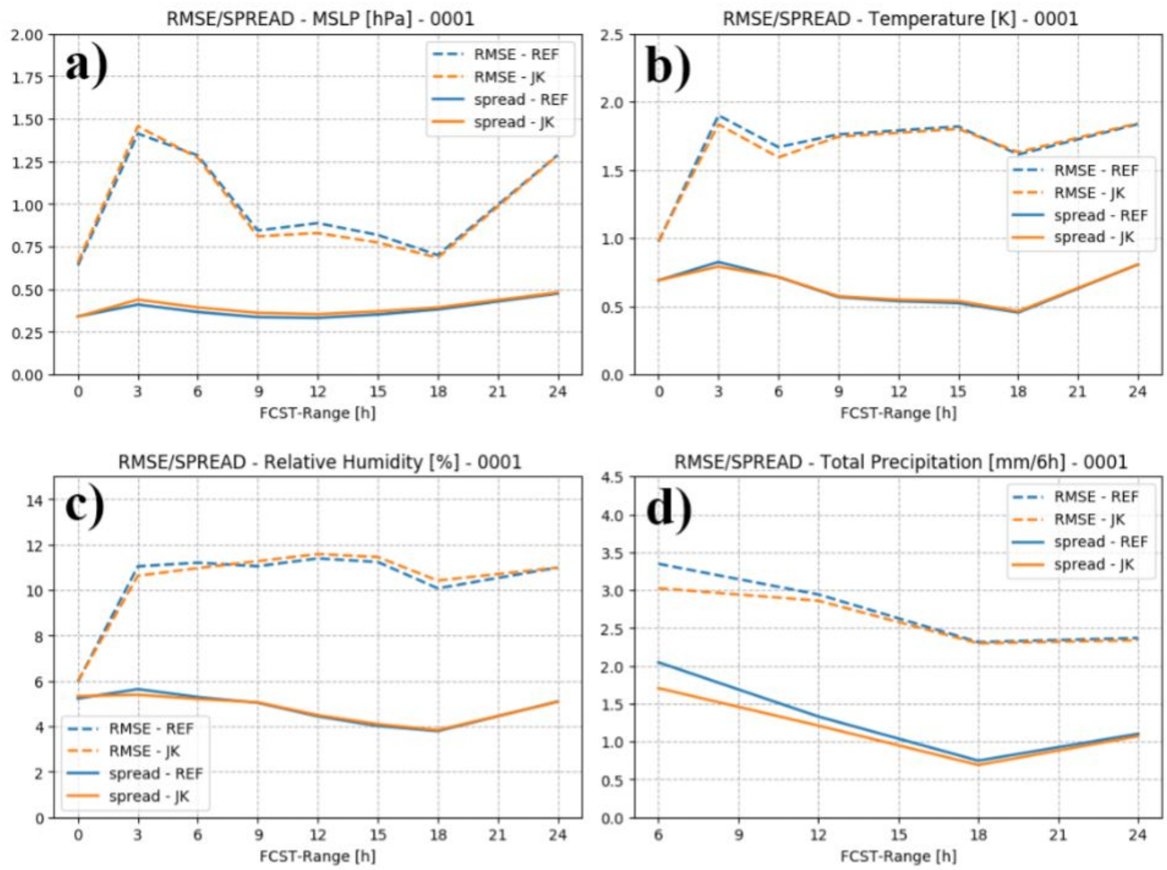

Figure 13: RMSE of ensemble mean (dashed) and ensemble spread (solid) of REF (AROME-EPS with 3DVar without Jk term) - blue and Jk - orange for (a) MSLP; (b) T2M; (c) RH2M and (d) RR06. The verification period is July 2016. Forecast ranges with statistically significant differences are marked with a bullet symbol.

The implemented Jk blending method has a positive impact on the ensemble error elimination for the upper-air fields at least for the first several hours of the integration, however the ensemble spread was sometimes reduced as well (see Fig.12). For surface fields the impact is rather neutral with slightly improved precipitation scores from the beginning of the integration (see Fig.13).

- **Topic 5: New ALADIN-LAEF phase I**

The problem of land-surface and sea-surface temperature fields in the initial conditions was successfully solved after we have isolated the very problem and contacted the GL experts from HIRLAM community. The bug was quickly localized by Ulf Andrae. He provided the fix for the code, which was then implemented and tested. Actually, there were two fixes applied to the GL tool. The first one to treat the proper surface fields interpolation (*ala/intp_ecmwf_surface.f90*) and the second one to correct the data extrapolation to e.g. deep fjords not visible in the ECMWF files (*grb/fill_missing.f90*). The first one was rather crucial (see Fig.14), while the second has only a small and geographically very localized impact (not shown).

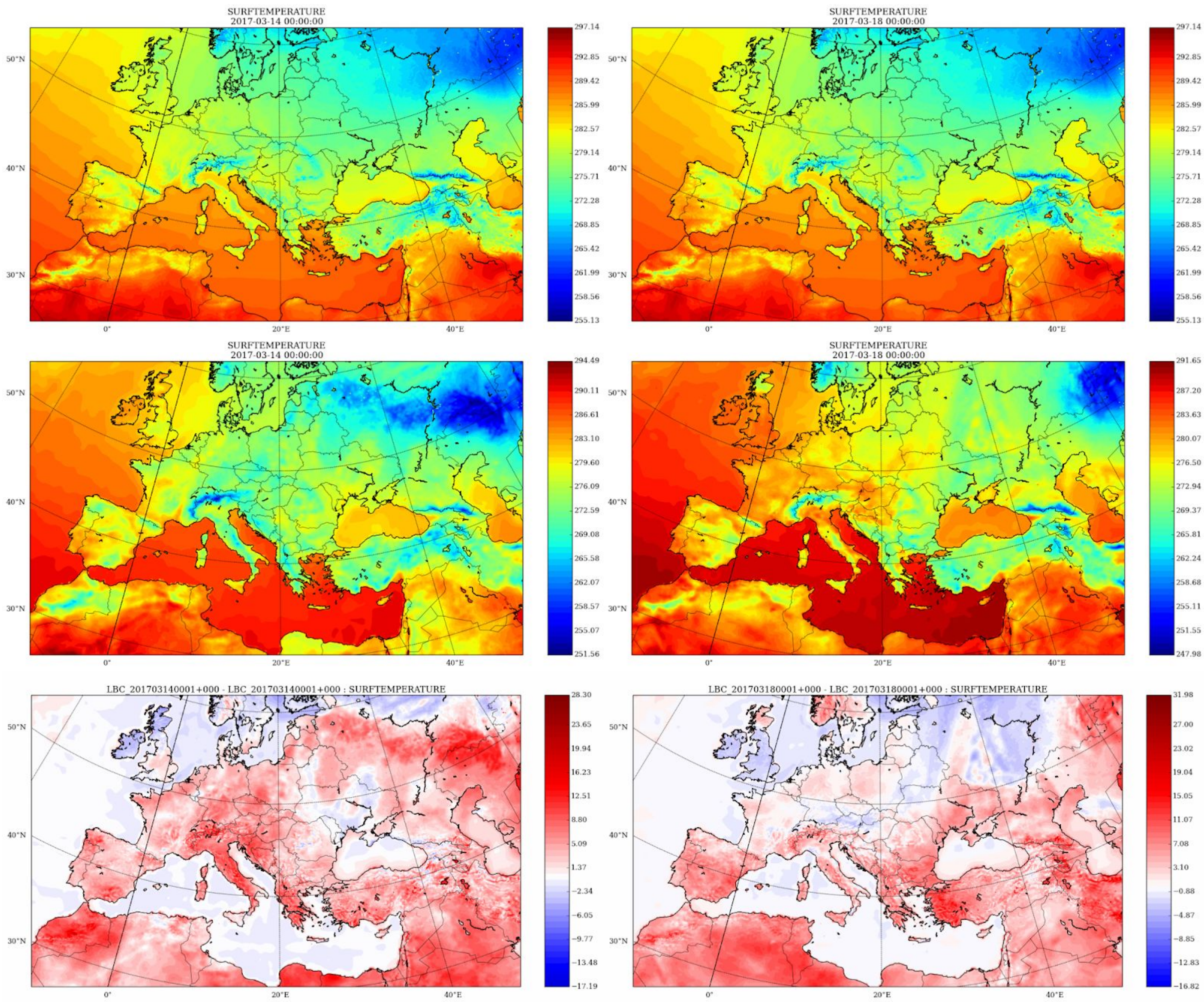

Figure 14: SST/LST initial conditions for 2 different days of March 2017 (left and right) produced with bugged version of interpolation tool in the first row and fixed one in the second row. The impact on SST/LST field is rather huge (shown in the third row as a difference between the first two).

The boundary conditions for 2-weeks period were recreated using corrected tools and downscaling of ECMWF-EPS was rerun for a clean reference to our LAEF experiments. Finally, new ALADIN-LAEF phase I configuration was put together, tested and verified against the mentioned reference. It contains ensemble of surface data assimilation (ESDA) with internally perturbed screen-level observations, upper-air spectral blending, stochastic perturbation of physics tendencies (SPPT) for ISBA prognostic fields and new ALARO-1 multiphysics (additionally to the model upgrade from cy36 to cy40, increased horizontal and vertical resolution and redefined domain). ALADIN-LAEF phase I configuration and its data flow is shown in the following scheme (see Fig.15).

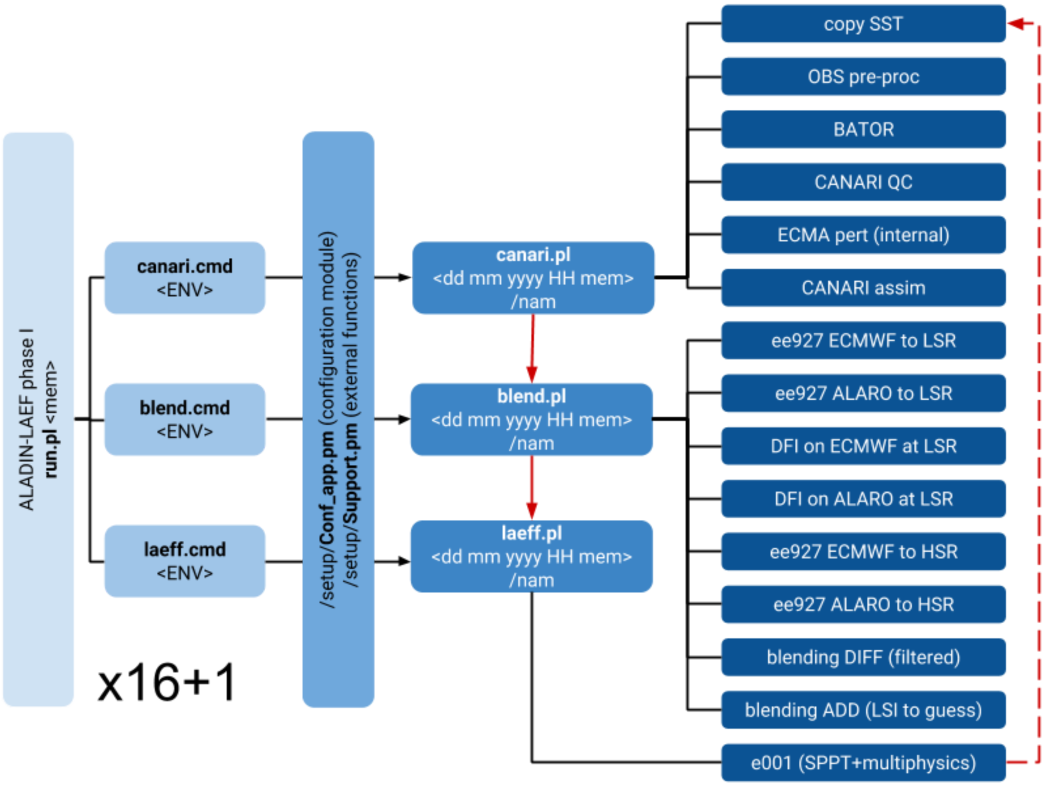

Figure 15: ALADIN-LAEF phase I configuration.

The added value of new ALADIN-LAEF over the downscaled ECMWF-EPS is obvious for the surface parameters (see Fig.16), while it is rather neutral in the upper-air (not shown).

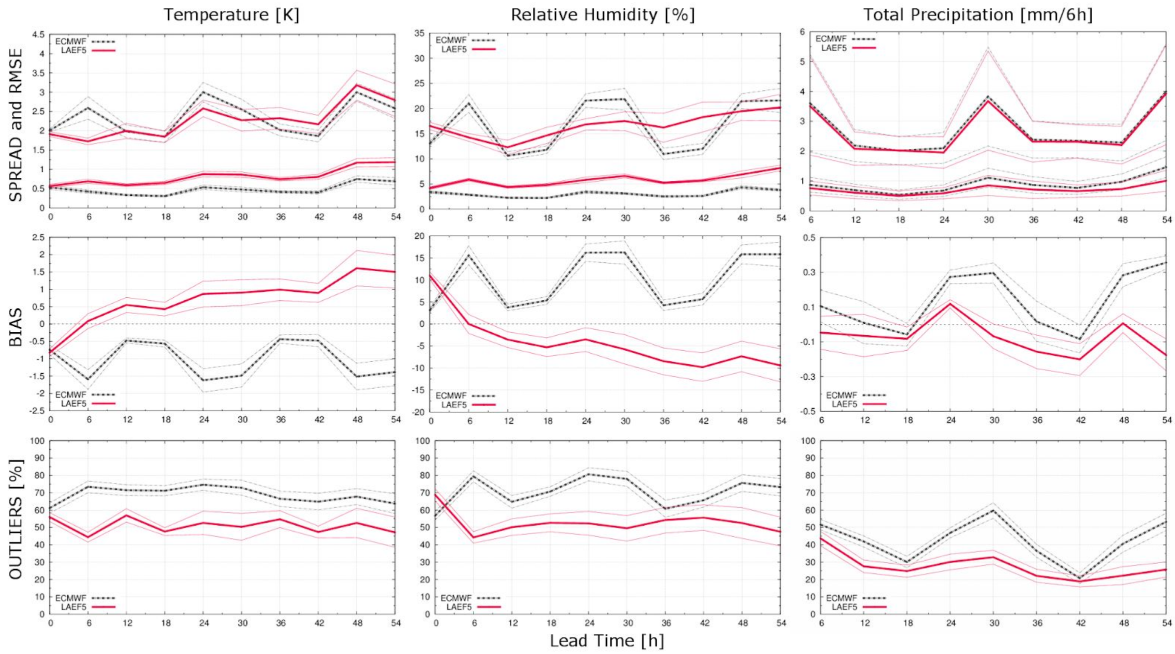

Figure 16: ALADIN-LAEF phase I (red lines) and ECMWF-EPS downscaling (gray dashed lines) for surface parameters. The thin lines denote 10% and 90% confidence intervals for given experiment.

However, due to several aspects (technical and even political) we have to admit, that our plan to get ALADIN-LAEF phase I into the operations by the end of the year 2017 was too ambitious. It is going to be postponed to the next year, but firstly some crucial questions must be answered: Who will provide the necessary billing units (~130 Mio SBU/year)? In case there won't be enough resources, what can be sacrificed in order to decrease its consumption (smaller domain/fewer members)? Who will participate on its operational maintenance?

- **Topic 6: Analog-based post-processing method**

The analog-based post-processing method can be used to improve the NWP model output and to estimate the probability distribution of the forecast. It exploits historical data within the specified analog training period for which both the NWP model and the observations are available. The analog-based method utilizes one consistent grid-point, which is usually the closest one to the measurement site. The best-matching historical forecasts to the current prediction - the analogs - may originate in any past date within the training period. Analogs are found independently for every forecast time and location. The verifying observations of the best-matching analogs are the members of the analog ensemble. The assumption is that the errors of the good analog forecasts are likely to be similar to the error of the current forecast.

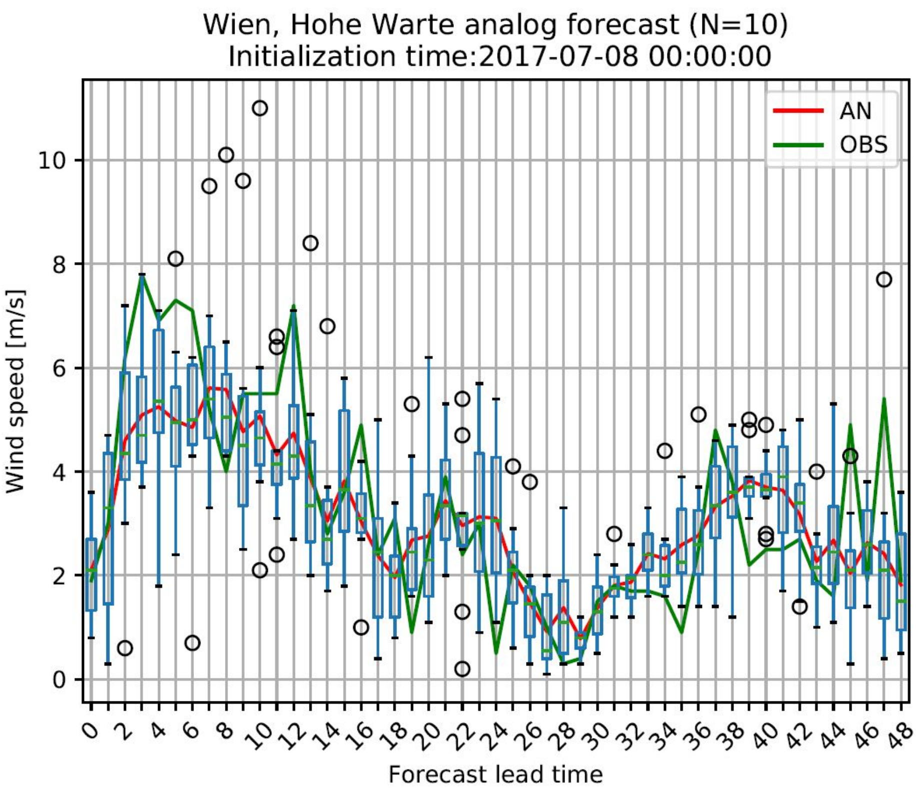

Figure 17: Wind speed forecast for Vienna based on the analog post-processing method. Red line is the ensemble mean (out of 10 members) and green line stands for the observed hourly values. Black circles are the outliers.

In the figure above one can see an example of 48-hours forecast for Vienna from the analog-based post-processing method. It is derived from the deterministic AROME run. The boxplot is analog ensemble output out of 10 members, where the red line represents the ensemble mean (AN forecast) and green line stands for the observations (OBS). The ensemble mean is considered at this point as an deterministic output from the given method and it is being tested. Once this part is done, the entire ensemble will be checked with the probabilistic verification measures.

Efforts: 12 PM (5.25 PM LACE stays)

Contributors: Martin Belluš (SHMU), Martin Dian (SHMU), Simona Taşcu (NMA), Raluca Pomaga (NMA), Christoph Wittmann (ZAMG), Yong Wang (ZAMG), Endi Keresturi (PhD at ZAMG), Iris Odak Plenković (DHMZ)

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.

The first phase of planned operational changes to ALADIN-LAEF towards the higher resolution (5 km / 60 levels / linear grid / cy40t1; IC: ESDA; model: SPPT+ALARO-1 MP) did not take place till the end of the year 2017. Hence, the technical details of operational suite running on CRAY HPCF at ECMWF are without any 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)
- multiphysics (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.

- **Topic 1: Development at OMSZ related to ensemble systems**

At OMSZ they are primarily focusing on their future convection-permitting EPS. Currently, the ALARO-EPS 8 km version is in operations till a new machine is available at OMSZ, where an high-resolution AROME-EPS can smoothly run with more members. New HPC is expected to be delivered about May 2018, where EDA and SPPT will be prefered methods for generating the perturbations. The combination of members from different runs (lagged EPS) is also in consideration. Till then, the operational ALARO-EPS configuration running at OMSZ is following:

- horizontal resolution: 8 km
- ensemble members: 11
- forecast length: +60 h (starting from 18 UTC only)
- coupling: ECMWF-EPS (since October 2016)

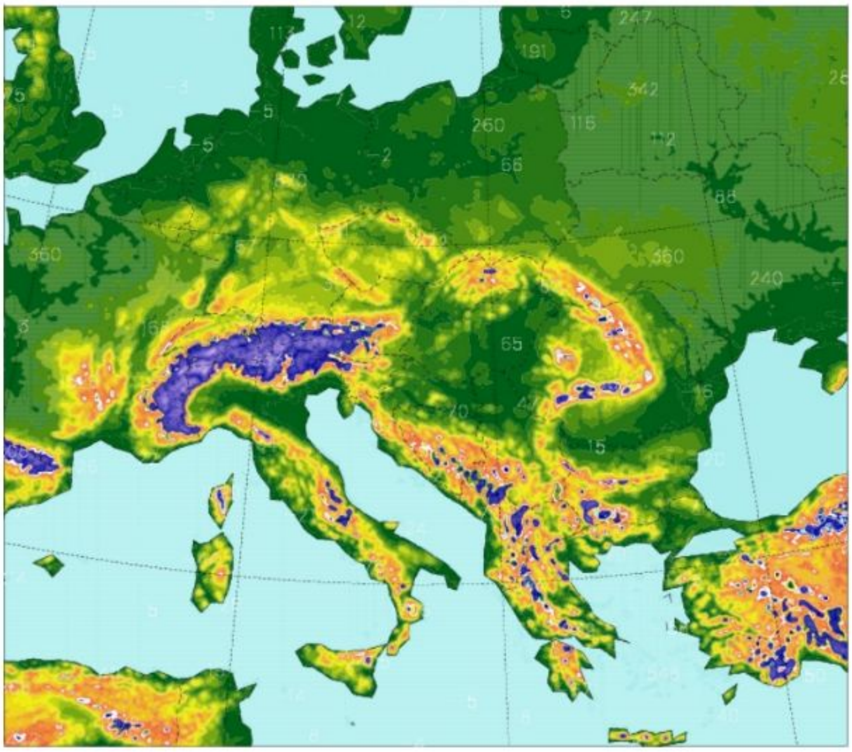

Figure 18: The operational domain of ALARO-EPS running at OMSZ once per day for 11 ensemble members with 8 km horizontal resolution.

- **Topic 2: AROME-EPS experiments at ZAMG**

Similar situation is being at ZAMG, where the computing resources for an operational setting of AROME-EPS are not sufficient even on new HPC. The new machine was delivered in October 2017, but will not be used for the operational EPS. ZAMG's new convection-permitting ensemble system C-LAEF (2.5 km) based on AROME model will be rather executed at ECMWF cluster. 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-EPS (time-lagged 6h)
- coupling frequency: 3h

The research work at ZAMG was mostly dedicated to further improvements of partial model tendencies perturbation within the AROME model framework. In this method the tendencies (T, Q, U, V) of radiation, turbulence, shallow convection and microphysics are perturbed separately after the call in apl_arome.F90. The novelty being the usage of separate random patterns. Not only the seed is changed as before, but also the horizontal and temporal scale is adapted for the different parameterizations (see Fig. 19).

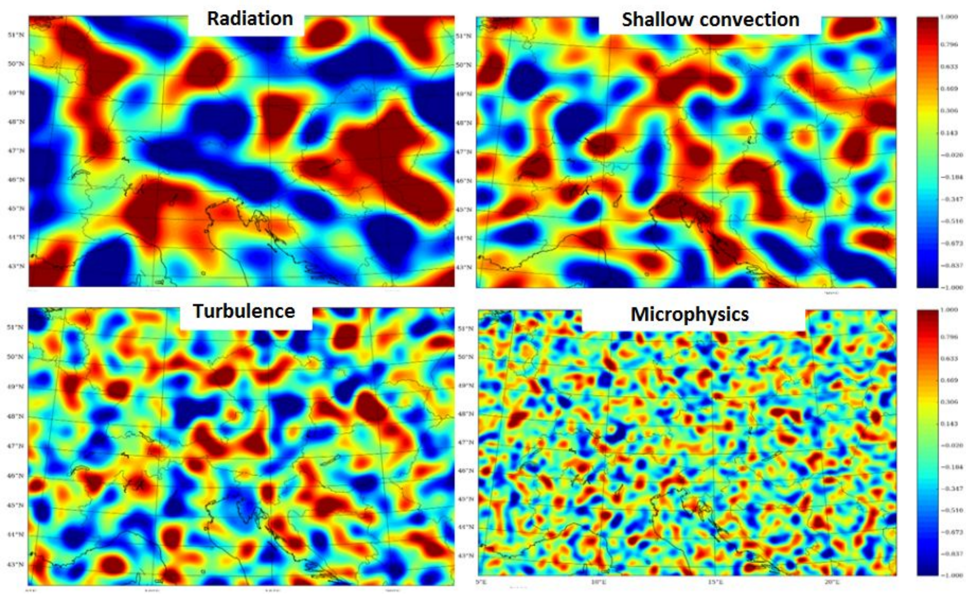

Figure 19: Different perturbation patterns with adapted scales for given physics schemes in AROME.

Microphysics receives the smallest scale perturbations since its uncertainties are naturally on a very small scale, while for instance the shallow convection uses larger ones. These different patterns can be adapted by namelist.

Verification over the test period (July 2016) has shown that this technique (black line in Fig.20) provides highest spread compared to standard SPPT (red line in Fig.20), partial tendencies approach with the same pattern size for all physics schemes (blue line in Fig.20) and the reference run without the stochastic physics (0-line in Fig.20). The scores are computed relative to the AROME-EPS without stochastic physics.

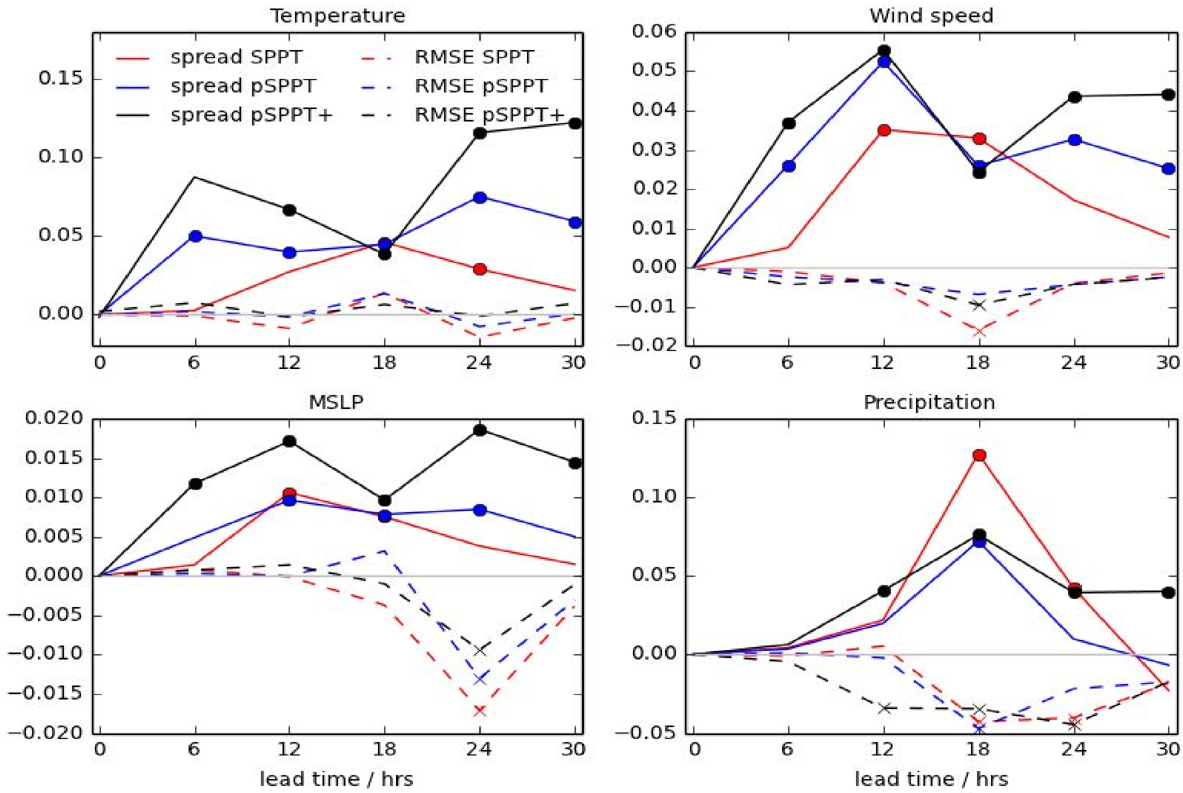

Figure 20: Relative spread and RMSE of the different tendency perturbation experiments in AROME-EPS for July 2016. Red line: original SPPT (perturbation of total tendencies); blue line: partial tendencies; black line: partial tendencies with adapted random patterns.

The AROME-EPS system currently under development at ZAMG has got the name C-LAEF for Convection permitting Limited Area Ensemble Forecasting. The implementation of a parameter perturbation scheme has been initiated. In this scheme key parameters like mixing length, autoconversion threshold, dissipation of TKE, critical Richardson number, etc. are perturbed by using different stochastic patterns with predefined scales according to the uncertainty range of the parameters. The perturbation range has been defined after the consultation with AROME physics experts at Meteo France (Yann Seity, Eric Bazile).

The turbulence scheme has been chosen because a tendency perturbation approach caused some model instabilities. As a next step the former partial tendency approach for shallow convection, radiation and microphysics was combined with the parameter perturbation in turbulence. The verification results over two 1-month test periods (July 2016 and January 2017) are promising (see Fig.21) and a publication is being prepared.

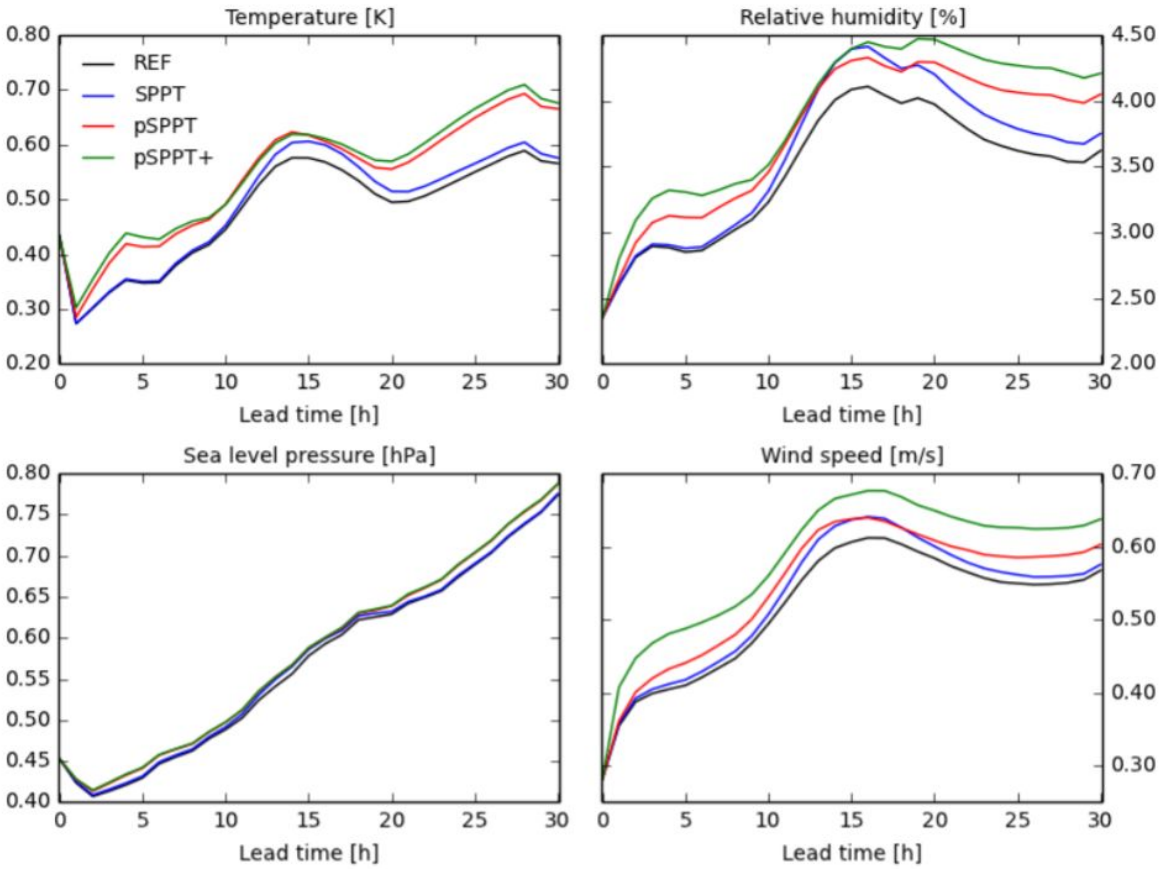

Figure 21: Ensemble spread averaged over July 2016 and January 2017 for 4 different C-LAEF experiments. REF is an ensemble without any stochastic physics, SPPT is the original ECMWF approach where total tendencies are perturbed, pSPPT is a partial tendency approach and pSPPT+ is a combination of pSPPT and parameter perturbation for the turbulence scheme.

- **Topic 3: Implementation of Stochastic Pattern Generator (SPG) in ALADIN code**

The main disadvantage of current pattern generator is that exactly the same time correlation belongs to all the spatial scales. While forecast error is bound to atmospheric motions it would be beneficial to represent the error by various scales with separated spatial and time correlations. With the current pattern generator the only possibility to meet this goal is to apply several random patterns during the same time. Such solution can handle more scales on a discrete way but can not represent the continuous spectra of the motions. Also the standard deviation should be controlled via namelist, but in practice it is much bigger for LAM. At the same time the horizontal correlation is much smaller and domain-size dependent.

For representing the model error at various scales there should be different time correlation values connected to different spatial correlation values. This feature is called "proportionality of scales", i.e. larger (shorter) spatial scales are associated with larger (shorter) temporal scales. The new pattern generator should be also correctly tunable by the namelist-defined values, which are close enough to the statistics calculated out of the generated fields. The theoretical background of SPG scheme is well-described by the inventors in an article (Tsyrulnikov and Gayfulin, 2016) and in a document attached to the external code of SPG.

In the external SPG program quite big part of the code is responsible for generation of Gaussian noise and Fast Fourier Transform (FFT). While such algorithms are also available in ALADIN code the rest of SPG is easier to implement. However, there were several challenges which have been tackled. Furthermore, it must be noted that in this implementation of SPG only a 2D version became available. Doing so was more simple and in accordance with the way how we (and also ECMWF) currently use the random patterns. The 3D version can be implemented later on as well.

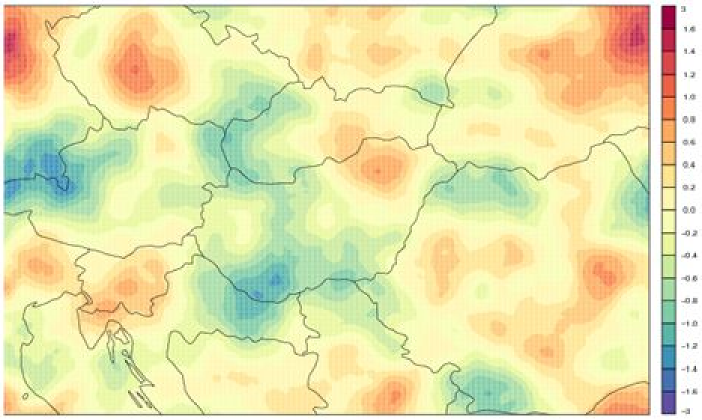

Figure 22: Random field generated by SPG (in ALADIN code implementation) for Hungarian AROME domain.

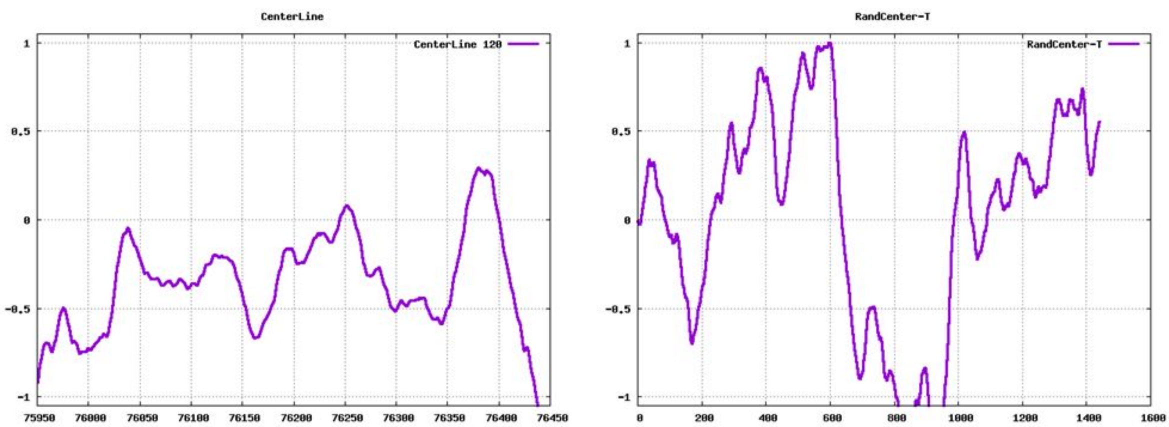

Figure 23: An x-oriented cross-section of the random pattern generated by SPG in ALADIN code implementation (left) and the time evolution of the random value of a given gridpoint in the center of the domain (right).

The statistical behaviour of the pattern was investigated over the 10 runs up to 6 hours. The standard deviation calculated over such a relatively big sample was 0.502 which is close enough to the namelist defined value. Note that with the current pattern generator this was around 1.2 if we omit clipping, which can significantly decrease the value at the end. Also the histogram of random numbers did not have a Gaussian shape with the current pattern generator (known issue), while with SPG it looks much better from this perspective (see Fig.24).

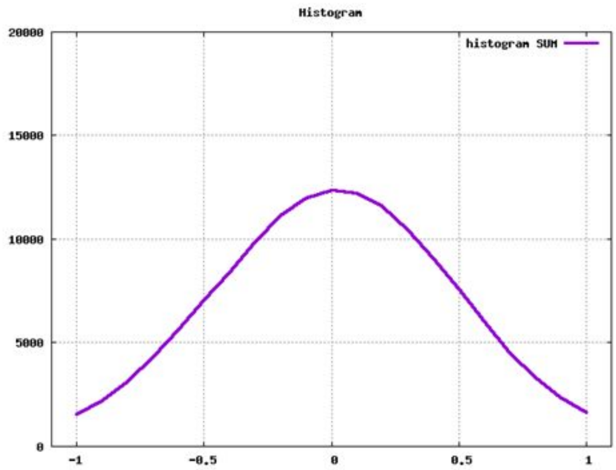

Figure 24: The histogram of random numbers averaged over the SPG generated random fields.

The new SPG can be used in SPPT tests, no matter if partial or total tendencies are involved. Even if there will exist the better than SPPT schemes in the future, it is very likely that for the model uncertainty representation the random patterns will be still utilized, which makes the future of SPG in an after-SPPT world. SPG can be very useful also from the surface perturbation aspects.

The code implementation was done under cy38, but as the modified routines are usually not touched from cycle to cycle, it should not be difficult to phase it into cy40 (this is planned).

Efforts: 13 PM (1.5 PM LACE stays)

Contributors: Réka Suga, Mihály Szűcs (both 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 forecasting system, either deterministic or probabilistic one. Knowing the statistical scores and limits of our forecasting system is crucial for further improvements. The huge amount of data must be processed, which requires an appropriate, optimized and flexible verification software. ALADIN-LAEF verification tool is being developed and maintained already for several years.

Efforts: 0.5 PM

Contributors: Simona Taşcu (NMA), Martin Belluš (SHMU)

Documentation: -

Status: Ongoing

S5 Action/Subject/Deliverable: Collaborations

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

The collaboration is currently being continued on SRNWP-EPS phase II project of EUMETNET. RC LACE is not directly involved, the cooperation is rather between the members' national meteorological services. Some related activities are carried out at Hungarian Meteorological Service. The second phase of the project was originally planned till the end of 2017, but it has been extended until 31st of December 2018. Current phase focuses on the development of new probabilistic methodologies to predict severe weather conditions like thunderstorms and fog and studying the underlying sensitivity of the models to soil conditions and the boundary layer.

As the merging procedure between the ALADIN and HIRLAM consortia already started by the preparation of common Rolling Work Plan for 2018, the collaboration with HIRLAM EPS group becomes more apparent. However, due to different work organization the collaboration is not so close yet as it would be adequate. If we want to cooperate on common issues, we can not restrict the communication to personal meetings twice a year on AHW and EWGLAM events.

Efforts: 0.5 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 run and time consuming activity, but indeed necessary.

In 2017 a lot of energy and time was invested into the preparation and finalization of a review paper devoted to the 27th anniversary of RC LACE regional cooperation. After some delays it was submitted to BAMS at the end of July, the revision of manuscript was then submitted in December 2017 and finally accepted for the publication in January 2018.

Efforts: 6 PM

Contributors: Yong Wang, Florian Weidle, Christoph Wittmann, Florian Meier, Clemens Wastl, Endi Keresturi (all ZAMG), Martin Belluš (SHMU), Mihály Szűcs (OMSZ), Simona Tascu (NMA)

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: 2 papers were published and several others are in preparation, 7 stay reports are available online via RC LACE portal (see the list of publications below)

Status: Ongoing

Documents and publications

Published papers:

- 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: "27 years of Regional Co-operation for Limited Area Modelling in Central Europe (RC LACE)", published online on 26 January 2018 in BAMS, DOI: 10.1175/BAMS-D-16-0321.1
- Ihász I., A. Mátrai, B. Szintai, M. Szűcs, I. Bonta, 2017: "Application of European numerical weather prediction models for hydrological purposes", published in Időjárás on January 2018, DOI: 10.28974/idojaras.2018.1.5

Submitted papers:

- 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

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:

- 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
- Martin Belluš, 2017: New ALADIN-LAEF phase I, Report on stay at ZAMG, 16/10~10/11, 2017, Vienna, Austria
- Iris Odak Plenković: Work on analog-based post-processing method, Report on stay at ZAMG, 13/11~09/12, 2017, Vienna, Austria

Activities of management, coordination and communication

- 28th LSC Meeting, 13-14 March 2017, Payerbach, Austria.
- RC LACE MG Meeting, 19 June 2017, Devín, Slovakia.
- 27th ALADIN Workshop & HIRLAM All Staff Meeting 2017, 3-7 April 2017, Helsinki, Finland (Martin Belluš, Clemens Wastl - oral presentations).
- EMS Annual Meeting: European Conference for Applied Meteorology and Climatology 2017, 4–8 September 2017, Dublin, Ireland (Clemens Wastl - oral presentation).
- 29th LSC Meeting, 21-22 September 2017, Ljubno ob Savinji, Slovenia.
- Annual Seminar ECMWF, 11-14 September 2017, Reading, UK (Florian Weidle - ALADIN-LAEF poster).
- 39th EWGLAM and 24th SRNWP meetings, 2-5 October 2017, Reading, UK (Martin Belluš - oral presentation).

The participants of RC LACE MG Meeting at Devín Castle ruins, Slovakia.

LACE supported stays – 6.75 PM

There were seven stays executed:

- Martin Dian [**S1**], 27 Mar ~ 21 Apr 2017, ZAMG (4 weeks)
- Martin Belluš [**S1**], 24 Apr ~ 19 May 2017, ZAMG (4 weeks)
- Mihály Szűcs [**S3**], 12 Jun ~ 21 Jul 2017, ZAMG (6 weeks)
- Raluca Pomaga [**S1**], 10 Jul ~ 4 Aug 2017, ZAMG (4 weeks)
- Simona Taşcu [**S1**], 10 Jul ~ 14 Jul 2017, ZAMG (1 week)
- Martin Belluš [**S1**], 16 Oct ~ 10 Nov 2017, ZAMG (4 weeks)
- Iris Odak Plenković [**S1**], 13 Nov ~ 9 Dec 2017, ZAMG (4 weeks)

Summary of resources [PM]

Subject	Manpower		LACE		ALADIN	
	plan	realized	plan	realized	plan	realized
S1: Optimization of LAEF	13	12	5.5	5.25		
S2: LAEF maintenance	1	0.5				
S3: AROME-EPS	10	13	1.5	1.5		
S4: EPS – Verification	1	0.5				
S5: Collaborations	2	0.5				
S6: Publications	6	6				
Total:	33	32.5	7	6.75	0	0