Regional Cooperation for Limited Area Modeling in Central Europe

LAM-EPS activities in LACE

Martin Belluš with contributions of Florian Weidle, Mihaly Szűcs, Simona Taşcu, Yong Wang and Endi Keresturi
Overview of activities 2015

Actual topics of our interest

- operational production of state-of-the-art regional EPS
- simulation of model uncertainty by SPPT
- convection-permitting ensembles
- high resolution 5 km ALADIN-LAEF
Overview of activities 2015

Actual topics of our interest

- operational production of state-of-the-art regional EPS
- simulation of model uncertainty by SPPT
- convection-permitting ensembles
- high resolution 5 km ALADIN-LAEF

Publishing Activities (2015)

- 1 published paper (Weather and Forecasting)
- 3 papers in peer-review (Springer, Weather and Forecasting, Monthly Weather Review)
- 1 paper in preparation
# ALADIN-LAEF (operational)

<table>
<thead>
<tr>
<th>ALADIN-LAEF (running at ECMWF)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>ensemble size</td>
<td>16 + 1</td>
</tr>
<tr>
<td>$\Delta x$ / vertical levels</td>
<td>10.9 km / 45</td>
</tr>
<tr>
<td>time-lagged coupling</td>
<td>ECMWF EPS (6h frequency)</td>
</tr>
<tr>
<td>runs per day</td>
<td>00 and 12 UTC (+72h forecast)</td>
</tr>
</tbody>
</table>
| IC perturbation | surface:  
  - ESDA by CANARI ($T_{2m}$, $H_{2m}$)  
  upper-air:  
  - breeding-blending |
| model perturbation | multi-physics:  
  - micro-physics  
  - deep/shallow convection  
  - radiation  
  - turbulence |
ALADIN-LAEF (operational)

**Surface IC uncertainty:** ESDA ($T_s$, $T_p$, $W_s$, $W_p$)

- CANARI assimilation tool based on the OI method
- assimilation of perturbed $T_{2m}$ and $H_{2m}$ OBS
- Gaussian distribution with zero mean and standard deviation equal to the observation errors
- each member has its own surface DA cycle

**temperature:**

$$\Delta T_s = \Delta T_{2m}$$

$$\Delta T_p = \frac{1}{2\pi} \Delta T_{2m}$$

**moisture:**

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

$$\Delta W_p = \alpha_p^T \Delta T_{2m} + \alpha_p^H \Delta H_{2m}$$
Upper-air IC uncertainty: breeding-blending (T, U, V, q, p_s)

- fortran programs for breeding
- e001, ee927 model configurations and DFI tool for blending

**breeding:**

\[
\alpha_p^k = A + \frac{1}{2} s(F_p^k - F_n^k)
\]

\[
\alpha_n^k = A - \frac{1}{2} s(F_p^k - F_n^k)
\]

**blending:**

\[
IC_{blend}^n = \alpha_{breed}^n + \left\{ (\alpha_{sv}^n)_{trunc} - (\alpha_{breed}^n)_{trunc} \right\}
\]

\[
IC_{blend}^n = LS^n + \alpha_{breed}^n
\]
ALADIN-LAEF (operational)

Upper-air IC uncertainty: breeding-blending (T, U, V, q, p_s)

- fortran programs for breeding
- e001, ee927 model configurations and DFI tool for blending

breeding:

\[ a^k_p = A + \frac{1}{2} s(F^k_p - F^k_n) \]
\[ a^k_n = A - \frac{1}{2} s(F^k_p - F^k_n) \]

blending:

\[ IC_{blend}^{n} = a_{breed}^{n} + \left\{ (a_{sv}^{n})_{trunc} - (a_{breed}^{n})_{trunc} \right\} \]
\[ IC_{blend}^{n} = LS^{n} + a_{breed}^{n} \]
### ALADIN-LAEF (Operational)

**Model uncertainty: multi-physics**

<table>
<thead>
<tr>
<th>member</th>
<th>MIC</th>
<th>DPC</th>
<th>SHC</th>
<th>RAD</th>
<th>TRB</th>
<th>GUD</th>
</tr>
</thead>
<tbody>
<tr>
<td>MP01</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MP02</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MP03</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MP04</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MP05</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MP06</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MP07</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MP08</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MP09</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MP10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MPxx</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**MIC - micro-physics**
- ALARO-0 using Xu-Randall type LS condensation
- ALARO-0 using Smith type LS condensation
- Lopez microphysics

**DPC - deep convection**
- 3MT (Modular Multi-scale Microphysics and Transport)
- Bougeault and Geleyn scheme
- 3MT + cellular automaton

**SHC - shallow convection**
- Geleyn (1987) based shallow convection
- Kain-Fritsch-Bechtold shallow convection scheme

**RAD - radiation**
- Geleyn et. al 2005, Rittern and Geleyn 1992
- RRTM and Morcrette 1991 (ECMWF)

**TRB - turbulence**
- pseudo-prognostic TKE, Geleyn et. al 2006
- Cuxart-Bougeault-Redelsperger prognostic TKE

**GUD - gust-wind diagnostics**
- classical ALADIN approach
- combination of ALADIN, Meso-NH and Brasseur
- TKE based approach (Meso-NH)
R&D - surface perturbations

Combination of IC and model uncertainties for SFC prognostic variables

In ALADIN-LAEF we already implemented and tested several perturbation methods:
- IC uncertainty: NCSB, ESDA (surface), breeding-blending (upper-air)
- model uncertainty: SPPT (surface), MP
- recently implemented SPPT was tested together with ESDA => positive impact
- perturbed SFC prognostic fields: $T_s$, $W_s$, $W_{si}$, $W_r$, $S_n$, $A_n$, $\rho_n$
- deep soil values are not perturbed

$$r \in \langle -C\sigma; +C\sigma \rangle$$

$$P'_{x_j}(\lambda, \varphi, h, t) = \{1 + \alpha(h)r_j(\lambda, \varphi, t)\}P_{x_j}$$

Spectral pattern (SPPT_ts025) :: L+0024 R+0030

[MIN:−0.500 MAX:0.500] [MIN:−0.500 MAX:0.500]
R&D - surface perturbations ...verification (BIAS)

Time series (+6h forecast) for 62 days of validation period
R&D - surface perturbations ...verification (RMSE)

Time series (+6h forecast) for 62 days of validation period
R&D - surface perturbations ...verification (OUTLIERS)

Time series (+6h forecast) for 62 days of validation period
R&D - surface perturbations ... verification (Spread Skill)

**temperature 2m:**

12h accumulated precipitation:

- Spread Skill Bins (surface) Range: 18
  - Temperature [K]
  - Period: 15.05.2011, 12 UTC - 15.07.2011, 12 UTC
  - +18h
  - +30h
  - +42h
  - +54h

- Spread Skill Bins (surface) Range: 30
  - Temperature [K]
  - Period: 15.05.2011, 12 UTC - 15.07.2011, 12 UTC
  - +18h
  - +30h
  - +42h
  - +54h

- Spread Skill Bins (surface) Range: 42
  - Temperature [K]
  - Period: 15.05.2011, 12 UTC - 15.07.2011, 12 UTC
  - +18h
  - +30h
  - +42h
  - +54h

- Spread Skill Bins (surface) Range: 54
  - Temperature [K]
  - Period: 15.05.2011, 12 UTC - 15.07.2011, 12 UTC
  - +18h
  - +30h
  - +42h
  - +54h

**ESDA+SPPT**

**ESDA**

**SPPT**
Towards higher resolutions in EPS

Atmospheric model (ECMWF)

<table>
<thead>
<tr>
<th></th>
<th>HRES</th>
<th>ENS</th>
<th>ENS Extended</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Current</td>
<td>Upgrade</td>
<td>Current</td>
</tr>
<tr>
<td>Spectral</td>
<td>T₉1279</td>
<td>TCO1279</td>
<td>T₉639</td>
</tr>
<tr>
<td>Gaussian grid</td>
<td>N640</td>
<td>O1280</td>
<td>N320</td>
</tr>
<tr>
<td>Horizontal grid resolution</td>
<td>~16 km</td>
<td>~9 km</td>
<td>~32 km</td>
</tr>
<tr>
<td>Dissemination (LL)</td>
<td>0.125°</td>
<td>0.1° and 0.125°</td>
<td>0.25°</td>
</tr>
<tr>
<td>Model Level</td>
<td>137</td>
<td>137</td>
<td>91</td>
</tr>
<tr>
<td>Vertical resolution</td>
<td>137</td>
<td>137</td>
<td>91</td>
</tr>
</tbody>
</table>

https://software.ecmwf.int/wiki/display/FCST/IFS+cycle+41r2+resolution+changes

ECMWF recently increased the horizontal resolution of both their deterministic and ensemble systems, even if it is bound to the upgrade of Gaussian grid only, while the spectral resolution of the model will remain unchanged. Nevertheless, they have reported several improvements of the forecast quality related to the better representation of model orography.
Towards higher resolutions in EPS

Comparison (based on CRPS) of current and previous operational IFS cycle verified by the corresponding analyses or SYNOP observations at 00 UTC for the period 10 August 2015 to 7 February 2016.

https://software.ecmwf.int/wiki/display/FCST/IFS+cycle+41r2+scorecard
R&D - ALADIN-LAEF 5 km

The first experiments with dynamical adaptation on 5 km

- driving model ALADIN-LAEF 11 km
- pure dynamical downscaling
- no surface assimilation nor EDA
- IC uncertainty interpolated
- no model uncertainty simulation
- 1 month verification period (dataset 2011, May-June)
- verified against ALADIN-LAEF 11 km
R&D - ALADIN-LAEF 5 km

Zoom over Slovakia - real grid-box size
R&D - ALADIN-LAEF 5 km

Zoom over Slovakia - real grid-box size
R&D - ALADIN-LAEF 5 km

LAEF 11 km

LAEF 5 km

Zoom over Austria - real grid-box size
R&D - ALADIN-LAEF 5 km

overestimated height

LAEF 11 km

LAEF 5 km

Zoom over Austria - real grid-box size
Regional Cooperation for Limited Area Modeling in Central Europe

R&D - ALADIN-LAEF 5 km ...verification (RMSE surface)

RMSE [surface] Mean Sea Level Pressure [hPa]
Period: 15.05.2011, 12 UTC - 15.06.2011, 12 UTC

RMSE [surface] Temperature [°C]
Period: 15.05.2011, 12 UTC - 15.06.2011, 12 UTC

RMSE [surface] Relative Humidity [%]
Period: 15.05.2011, 12 UTC - 15.06.2011, 12 UTC

RMSE [surface] Wind Speed [m/s]
Period: 15.05.2011, 12 UTC - 15.06.2011, 12 UTC

LAEF 5 km
LAEF 11 km
Regional Cooperation for
Limited Area Modeling in Central Europe

R&D - ALADIN-LAEF 5 km ...verification (SPR. surface)

```
<table>
<thead>
<tr>
<th>LAEF 5 km</th>
<th>LAEF 11 km</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ensemble spread [surface]</td>
<td>Mean Sea Level Pressure [hPa]</td>
</tr>
<tr>
<td>Period: 15.05.2011, 12 UTC - 15.06.2011, 12 UTC</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>LAEF 5 km</th>
<th>LAEF 11 km</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind Speed [m/s]</td>
<td>Relative Humidity [%]</td>
</tr>
<tr>
<td>Period: 15.05.2011, 12 UTC - 15.06.2011, 12 UTC</td>
<td></td>
</tr>
</tbody>
</table>
```
Regional Cooperation for
Limited Area Modeling in Central Europe

R&D - ALADIN-LAEF 5 km ...verification (OUTL. surface)

26th ALADIN Workshop & HIRLAM All Staff Meeting 2016
4-8 May 2016, Lisbon, Portugal
R&D - ALADIN-LAEF 5 km ...verification (850 hPa)

- smaller RMSE
- better SPREAD
- reduced BIAS

RMSE/SPREAD/BIAS [850 hPa]
Temperature [K]
Period: 15.05.2011, 12 UTC - 15.06.2011, 12 UTC

RMSE/SPREAD/BIAS [850 hPa]
Relative Humidity [%]
Period: 15.05.2011, 12 UTC - 15.06.2011, 12 UTC

RMSE/SPREAD/BIAS [850 hPa]
Wind Speed [m/s]
Period: 15.05.2011, 12 UTC - 15.06.2011, 12 UTC
R&D - ALADIN-LAEF 5 km

The first experiments with dynamical adaptation on 5 km

- driving model ALADIN-LAEF 11 km
- pure dynamical downscaling
- no surface assimilation nor EDA
- IC uncertainty interpolated
- no model uncertainty simulation
- 1 month verification period (dataset 2011, May-June)
- verified against ALADIN-LAEF 11 km

Another idea (CPU cheaper solution)

- double the grid-point count
- keep the original spectral truncation
- new clim files with enhanced orography
- what will be the benefit from ESDA on higher resolution?
R&D - Stochastic physics in CY40T1 with ALARO-1

- implementation of surface SPPT in CY40T1
- bug discovered in the export version of CY40T1 (bf5)

Physics tendency of Ts (CY40T1) :: L+0018 R+0024

**Perturbed physics tendency** of surface temperature in bugfixed CY40T1 for range +18 (06h in the morning, left) and +24 (12h at noon, right).

**Surface temperature** in bugfixed CY40T1 with SPPT (left) and reference without SPPT (right) for range +18 (morning, up) and +24 (noon, bottom).
Results from the statistical verification of one month period show significant improvement in CY40T1 over CY38T1 for screen-level temperature forecast during night/morning hours, but that is most likely due to improved physics in ALARO-1 package. Nevertheless, some slight enhancement of the scores obviously came from SPPT as well (spread, outliers).
R&D - Stochastic physics in CY40T1 with ALARO-1

Results from the statistical verification of one month period show significant improvement in CY40T1 over CY38T1 for screen-level temperature forecast during night/morning hours, but that is most likely due to improved physics in ALARO-1 package. Nevertheless, some slight enhancement of the scores obviously came from SPPT as well (spread, outliers).
Results from the statistical verification of one month period show significant improvement in CY40T1 over CY38T1 for screen-level temperature forecast during night/morning hours, but that is most likely due to improved physics in ALARO-1 package. Nevertheless, some slight enhancement of the scores obviously came from SPPT as well (spread, outliers).
Several experiments were already done using AROME-EPS on 2.5 km horizontal resolution for the Hungarian domain, without noticing any significant impact of the SPPT scheme. Therefore, the recent experiments were done using ALARO on 8 km horizontal resolution with the significantly lower computational costs in comparison to AROME. It is expected that such “scheme-oriented” tests would be valid also for AROME. Three issues were covered:

- spectral random pattern generator in LAM versions
- impact of the modification of vertical tapering function
- dimensional extension of SPPT

\[ r \in \langle -C\sigma; +C\sigma \rangle \]

\[ P'_{\lambda, \varphi, h, t} = \{1 + \alpha(h) r_j(\lambda, \varphi, t)\} P_{x_j} \]

**Histogram of random number values** of the spectral pattern generator for \(\sigma=0.5\), clipping ratio=2 (left) and for \(\sigma=0.25\), clipping ratio=4 (right).
Originally the same random number is used for all the physics tendencies in a given vertical column. For the two wind components on a given level it means that both of them are in principle multiplied by the same number. Thus the length of the wind tendency vector is changed but not the direction. The new idea is to apply various random numbers, one for each of the 4 prognostic variables. That can ensure bigger variability because not only the size of the tendency vector but also its direction is perturbed.

**RMSE of the ensemble mean and the SPREAD of the ensemble for the temperature at 2m (left) and temperature at 850 hPa (right) for different experiments (red lines - downscaling of PEARP, green lines - original SPPT, blue and purple lines - SPPT with the independent perturbations of T, q, U, V).**
Publications

Published papers


Submitted papers (currently in review)

- Szűcs M., A. Horanyi, G. Szépszó, 2015: “Ensemble forecasting in numerical weather prediction”, Mathematical Problems in Meteorological Modelling, Springer (waiting for the final decision)

Papers in preparation for the submission

- Taşcu S., Y. Wang, Ch. Wittmann, F. Weidle, 2015: “Forecast skill of regional ensemble system comparing to the higher resolution deterministic model”, in preparation for local meteorological journal (Romania)
Outlook

Current goals and future plans

● continue providing the probabilistic forecasts based on **ALADIN-LAEF** for all RC LACE partners (00, 12 UTC up to 72 hrs)

● **revision of MP** with use of state-of-the-art ALARO-1 physics on CY40T1

● reduced number of MP members supplemented by **SPPT** (surface and upper-air)

● implementation of **BlendVar** (ENS 3D-Var + upper-air spectral blending)

● testing/implementing ALADIN-LAEF at **5 km** with ALARO-1 physics

● **AROME-EPS** development (SPPT, coupling strategy, EDA, MP)

● closer collaboration with **HIRLAM** group on current LAM-EPS issues
Obrigado pela sua atenção!