Regional Cooperation for
Limited Area Modeling in Central Europe

LACE
nwp central europe

LAM-EPS activities in LACE

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

DHMZ   SHMU   OMSZ   ZAMG   ROMANIA ANM

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

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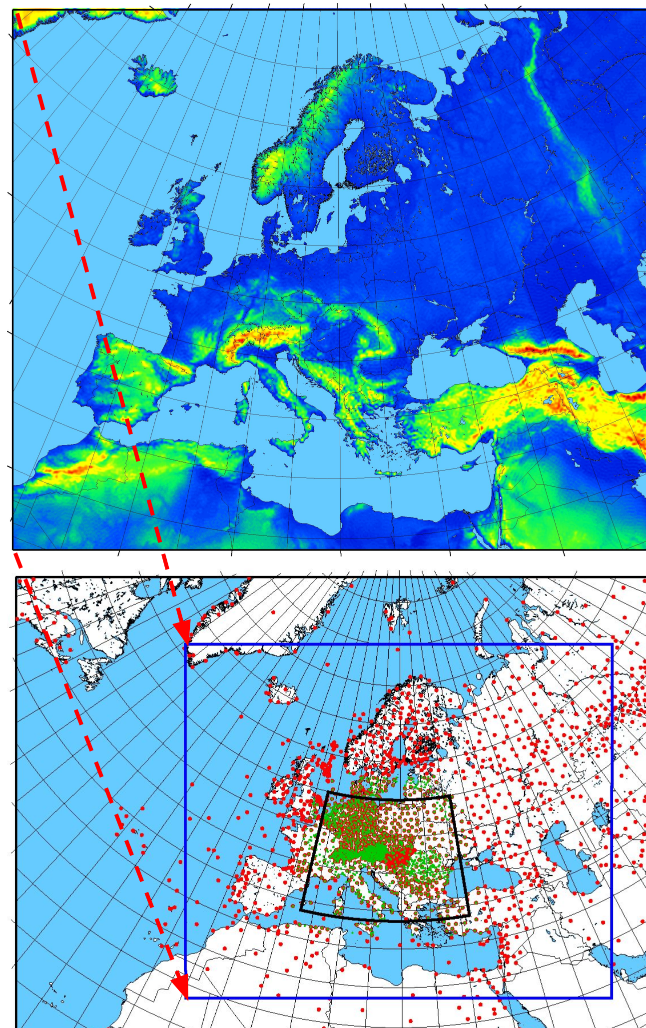
Publishing Activities (2015)

- 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)

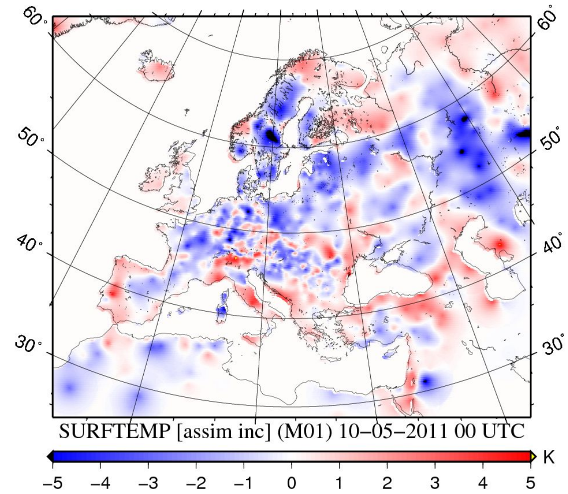
ALADIN-LAEF (running at ECMWF)	
ensemble size	16 + 1
Δx / vertical levels	10.9 km / 45
time-lagged coupling	ECMWF EPS (6h frequency)
runs per day	00 and 12 UTC (+72h forecast)
IC perturbation	surface: • ESDA by CANARI (T_{2m}, H_{2m}) upper-air: • breeding-blending
model perturbation	multi-physics: • 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:

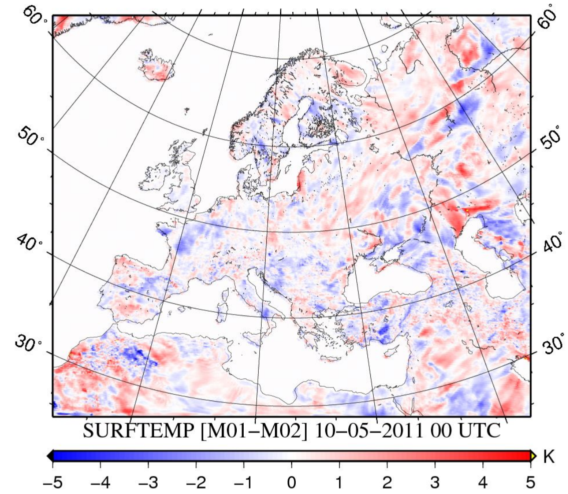
$$\Delta T_s = \Delta T_{2m}$$

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

moisture:

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

$$\Delta W_p = \alpha_p^T \Delta T_{2m} + \alpha_p^H \Delta H_{2m}$$



ALADIN-LAEF (operational)

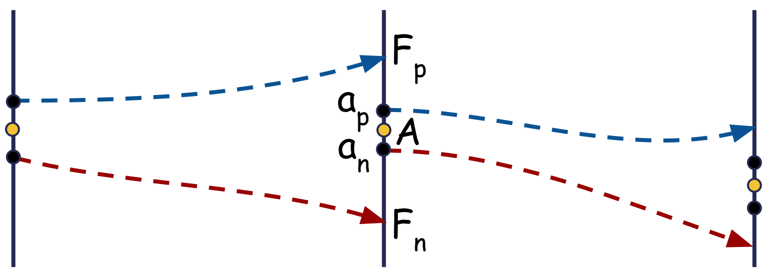
Upper-air IC uncertainty: **breeding-blending (T, U, V, q, p_s)**

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

breeding:

$$a_p^k = A + \frac{1}{2} s(F_p^k - F_n^k)$$

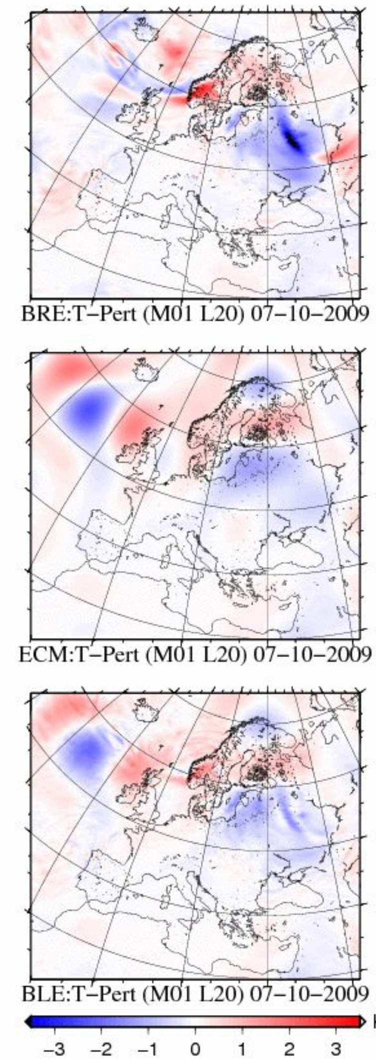
$$a_n^k = A - \frac{1}{2} s(F_p^k - F_n^k)$$



blending:

$$IC_{blend}^n = a_{breed}^n + \{ \overline{(a_{sv}^n)_{trunc}} - \overline{(a_{breed}^n)_{trunc}} \}$$

$$IC_{blend}^n = LS^n + a_{breed}^n$$



BRE:T−Pert (M01 L20) 07−10−2009

ECM:T−Pert (M01 L20) 07−10−2009

BLE:T−Pert (M01 L20) 07−10−2009

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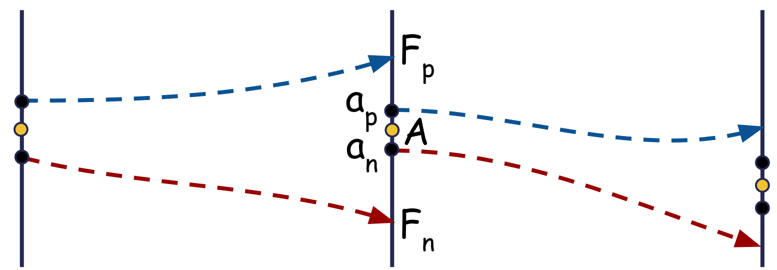

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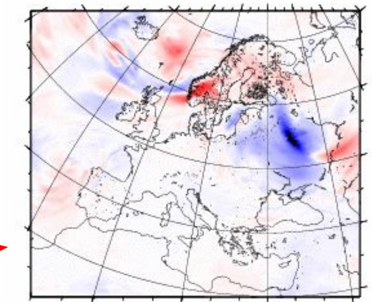
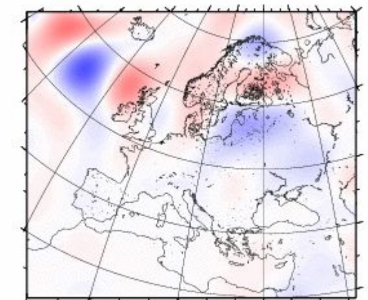
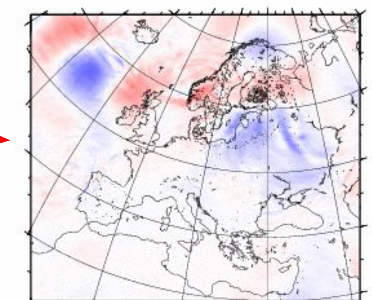

BRE:T–Pert (M01 L20) 07–10–2009


ECM:T–Pert (M01 L20) 07–10–2009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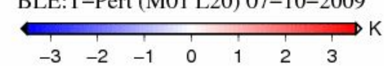
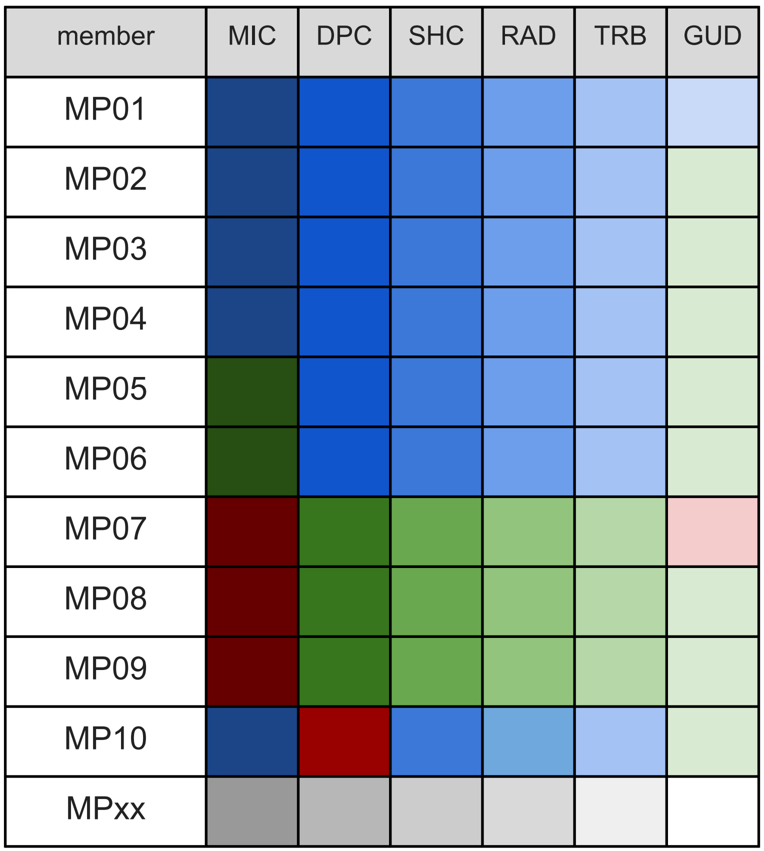


ALADIN-LAEF (operational)

Model uncertainty: multi-physics



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. all 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

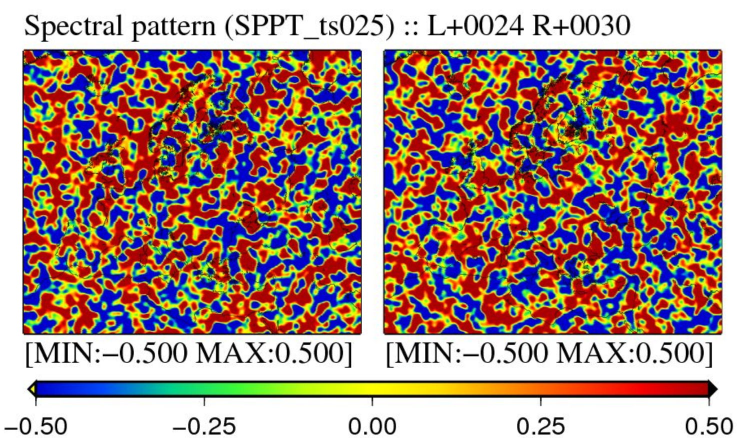
Combination of IC and model uncertainties for SFC prognostic variables

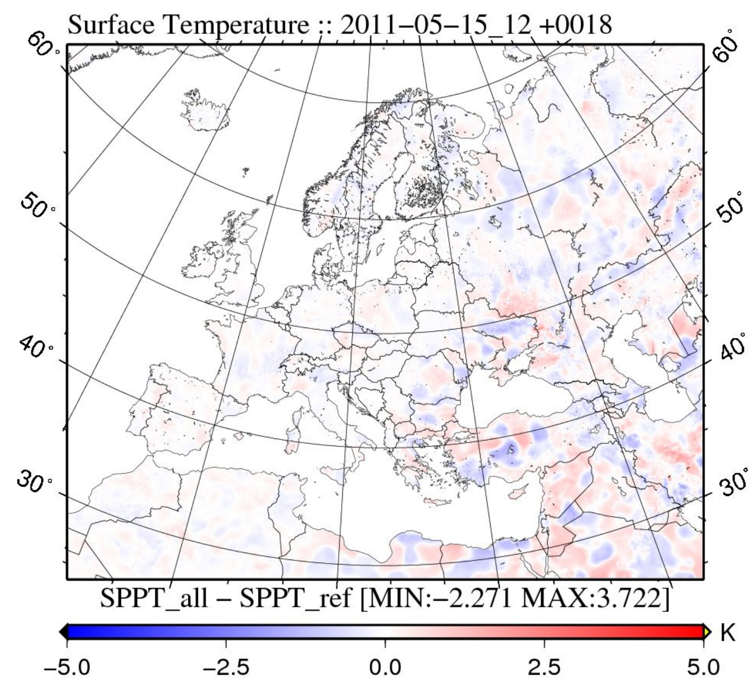
In ALADIN-LAEF we already implemented and tested several perturbation methods:

- 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: $\mathbf{T_s}$, $\mathbf{W_s}$, $\mathbf{W_{si}}$, $\mathbf{W_r}$, $\mathbf{S_n}$, $\mathbf{A_n}$, $\boldsymbol{\rho_n}$
- deep soil values are not perturbed

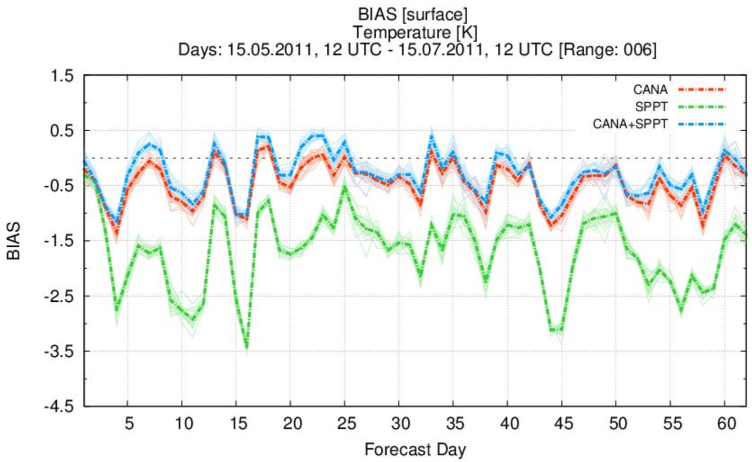
$$r \in \langle -C\sigma; +C\sigma \rangle$$

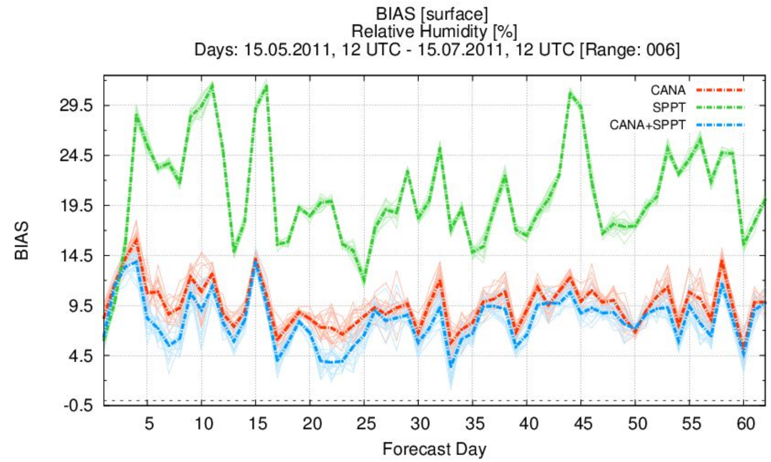
$$P'_{x_j}(\lambda,\varphi,h,t) = \{1 + \alpha(h) r_j(\lambda,\varphi,t)\} P_{x_j}$$

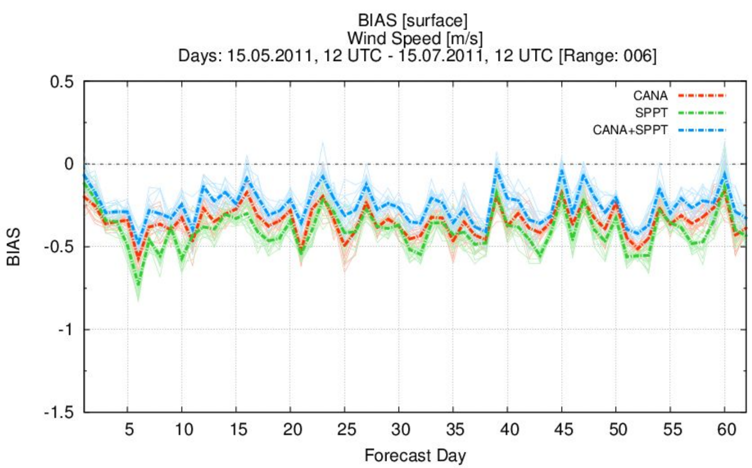




R&D - surface perturbations ...verification (BIAS)



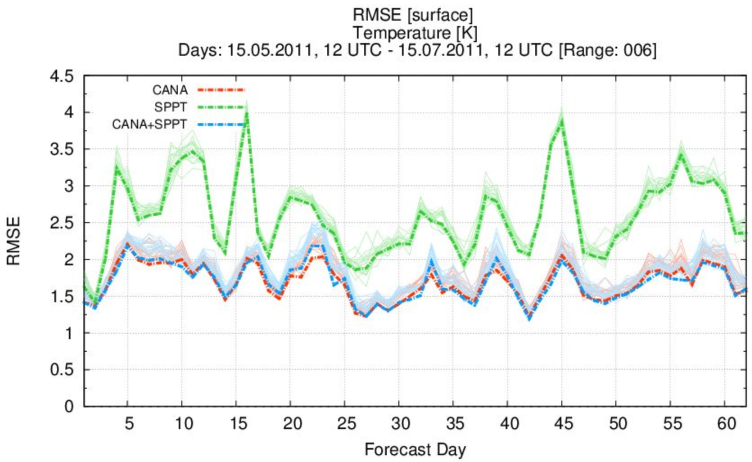


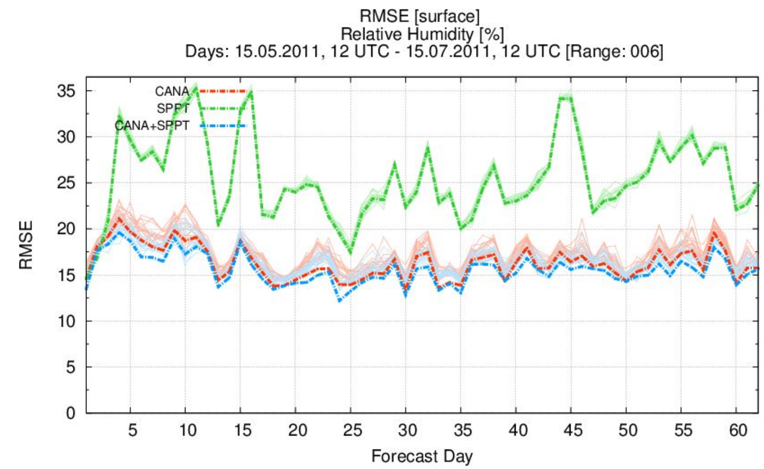


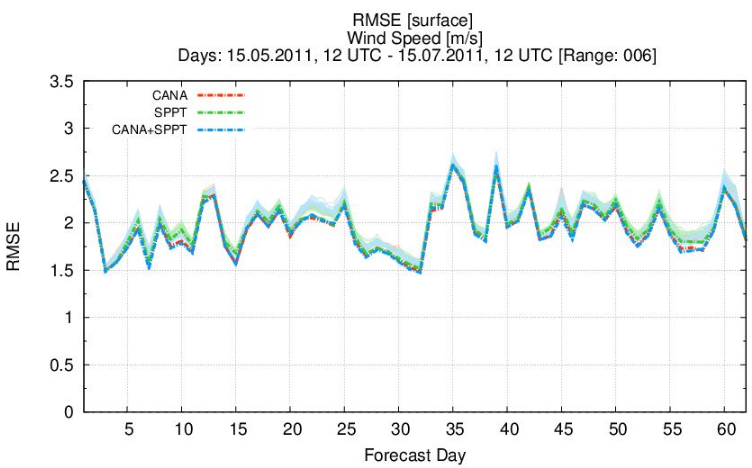
ESDA+SPPT
ESDA
SPPT

Time series (+6h forecast) for 62 days of validation period

R&D - surface perturbations ...verification (RMSE)



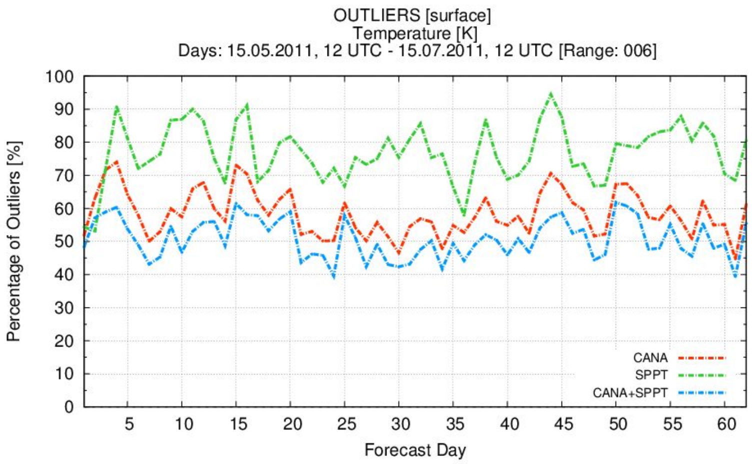


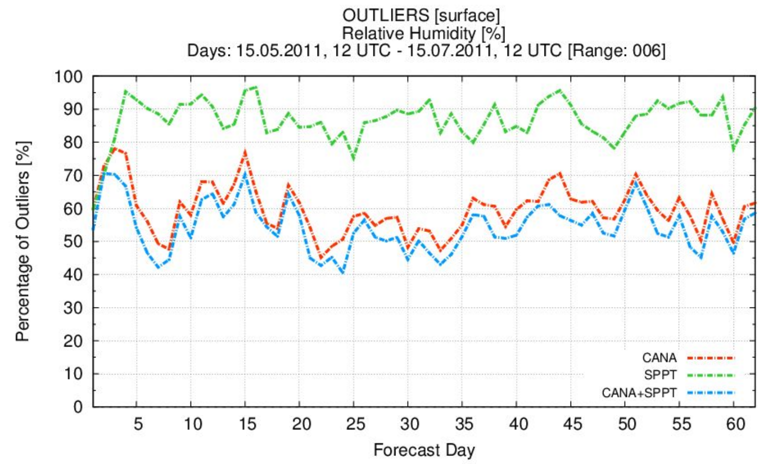


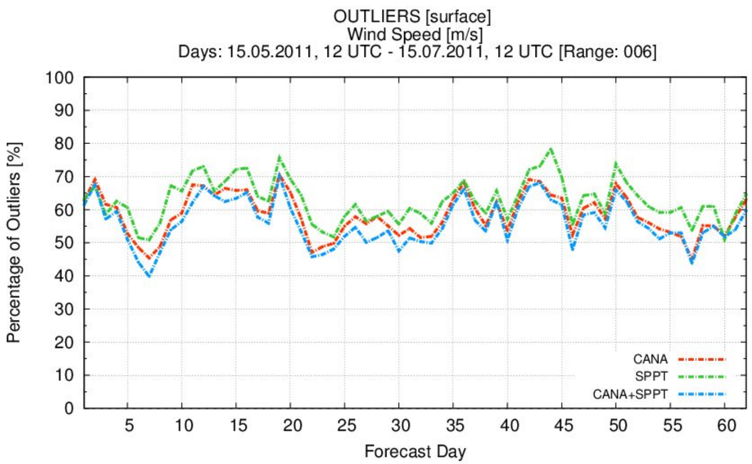
ESDA+SPPT
ESDA
SPPT

Time series (+6h forecast) for 62 days of validation period

R&D - surface perturbations ...verification (OUTLIERS)





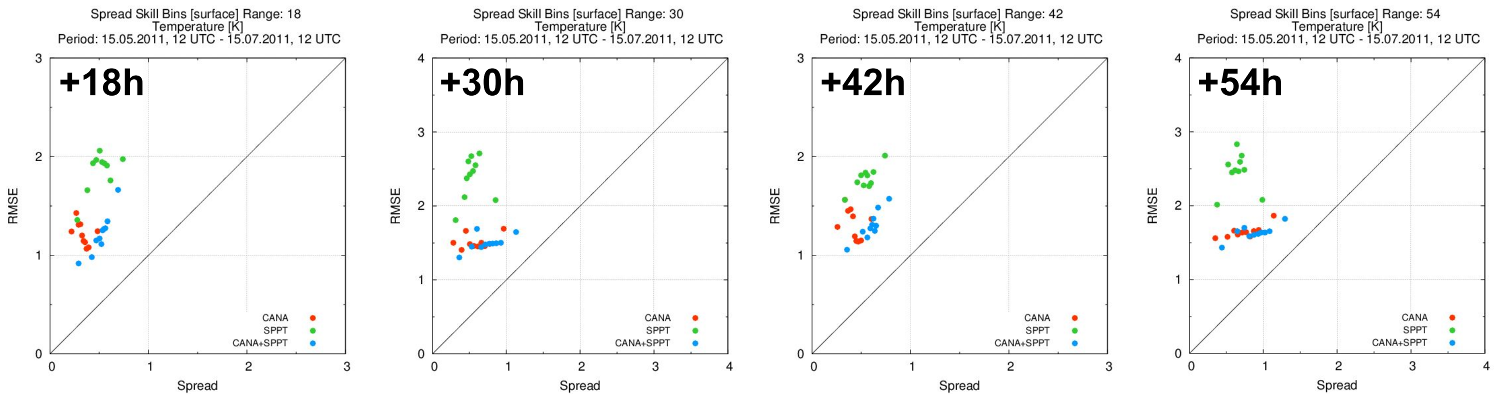


ESDA+SPPT
ESDA
SPPT

Time series (+6h forecast) for 62 days of validation period

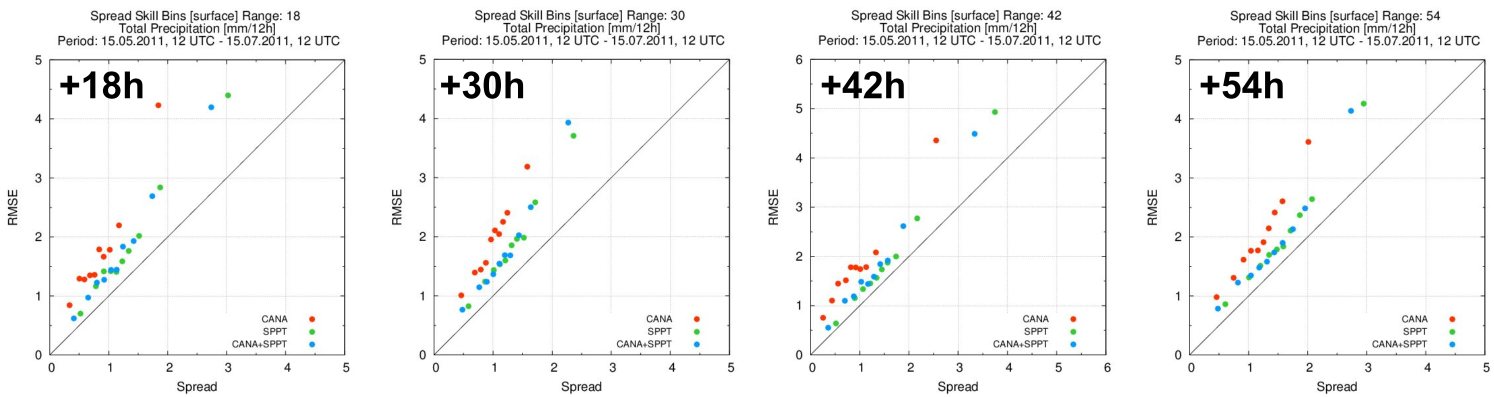
R&D - surface perturbations ...verification (Spread Skill)

temperature 2m:



ESDA+SPPT
ESDA
SPPT

12h accumulated precipitation:



Towards higher resolutions in EPS

Atmospheric model (ECMWF)

	HRES		ENS				ENS Extended	
			Day 0 - 10		Day 11 - 15		Day 16 - 46	
	Current	Upgrade	Current	Upgrade	Current	Upgrade	Current	Upgrade
Spectral	T_L1279	$T_{CO}1279$	T_L639 →	$T_{CO}639$	T_L319	$T_{CO}639$	T_L319	$T_{CO}319$
Gaussian grid	N640	O1280	N320	O640	N160	O640	N160	O320
Horizontal grid resolution	~16 km	~9 km	~32 km	~18 km	~64 km	~18 km	~64 km	~36 km
Dissemination (LL)	0.125°	0.1° and 0.125°	0.25°	0.2° and 0.25°	0.5°	0.2° and 0.25°	0.5°	0.4° and 0.5°
Model Level Vertical resolution	137	137	91	91	91	91	91	91

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

Europe	against analysis	Wind speed	850hPa	
		Temperature		
		Geopotential	500hPa	
			1000hPa	
	against observations	10m wind		
		2m temperature		
		24h precipitation		
Extratropical Northern Hemisphere	against analysis	Wind speed	850hPa	
		Temperature		
		Geopotential	500hPa	
			1000hPa	
	against observations	10m wind		
		2m temperature		
		24h precipitation		

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

- ▲ CY41r2 **better** than CY41r1 **statistically highly significant**
- ▴ CY41r2 **better** than CY41r1 **statistically significant**
- CY41r2 better than CY41r1, yet not statistically significant
- not really any difference between CY41r1 and CY41r2
- CY41r2 worse than CY41r1, yet not statistically significant
- ▾ CY41r2 **worse** than CY41r1 **statistically significant**
- ▼ CY41r2 **worse** than CY41r1 **statistically highly significant**

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.

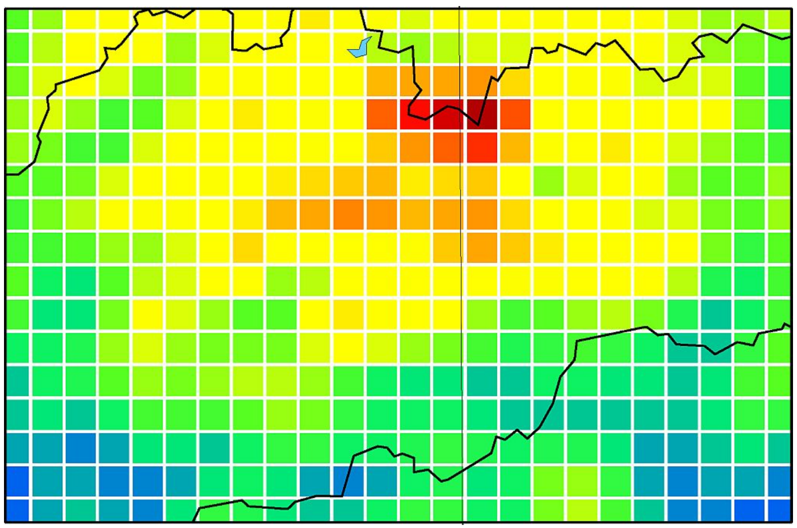
R&D - ALADIN-LAEF 5 km

The first experiments with dynamical adaptation on 5 km

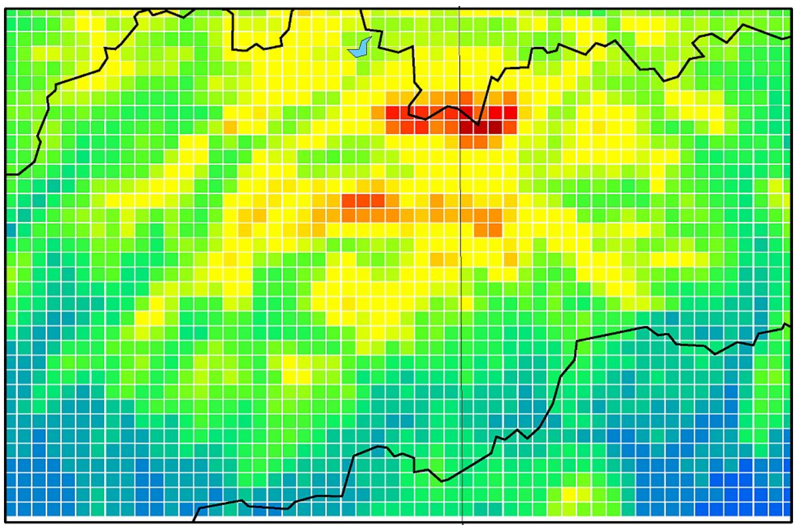
- driving model ALADIN-LAEF 11 km
- pure dynamical downscaling
- no surface assimilation nor EDA
- IC uncertainty interpolated
- no model uncertainty simulation
- 1 month verification period (dataset 2011, May-June)
- verified against ALADIN-LAEF 11 km

R&D - ALADIN-LAEF 5 km

LAEF 11 km

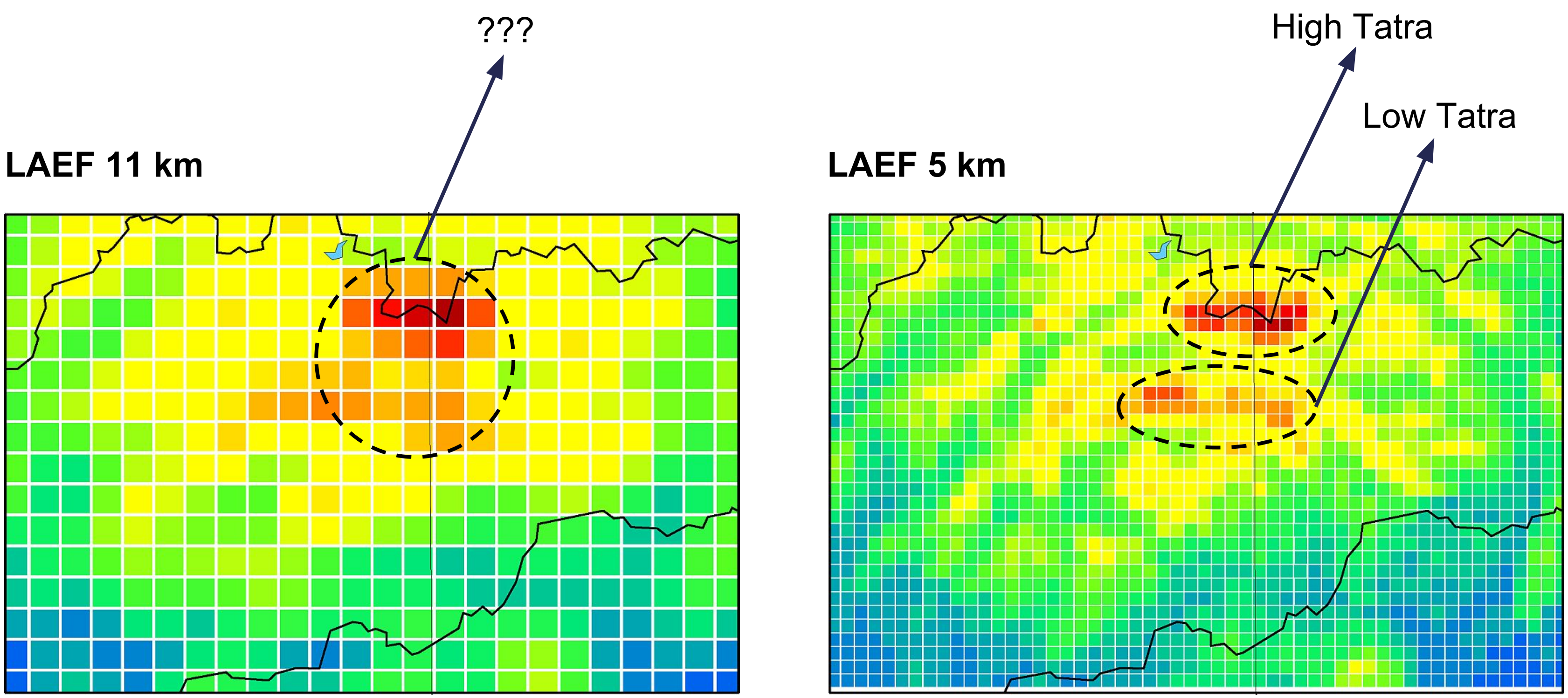


LAEF 5 km



Zoom over Slovakia *- real grid-box size*

R&D - ALADIN-LAEF 5 km



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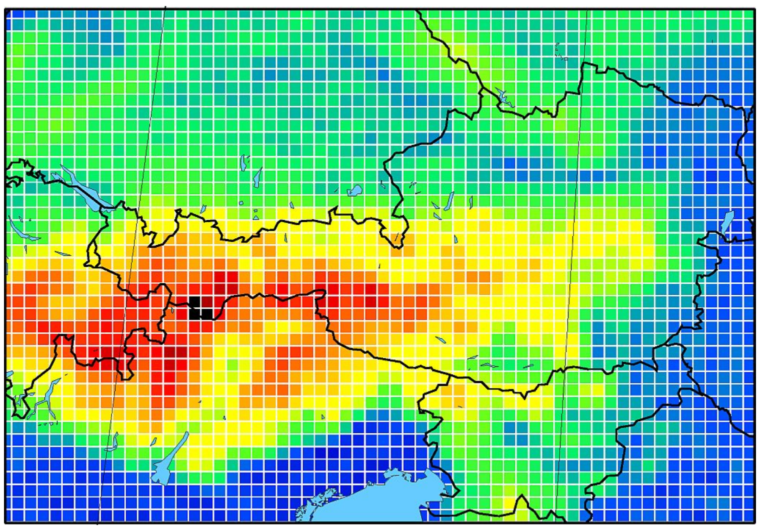
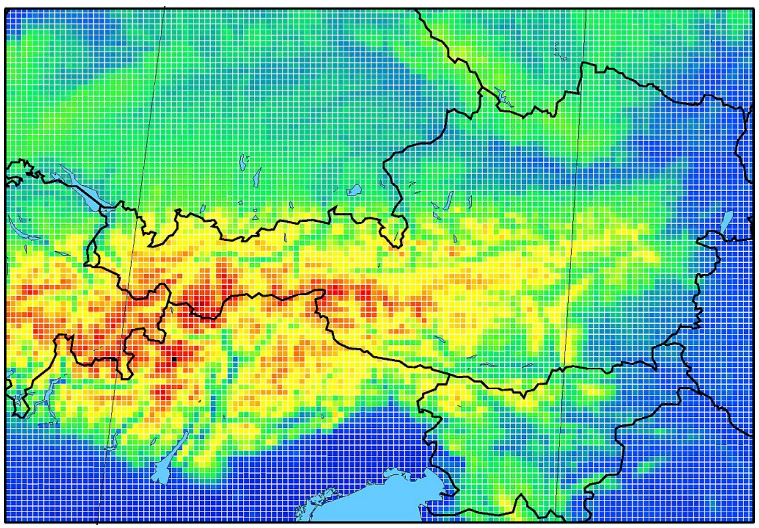


LAEF 5 km

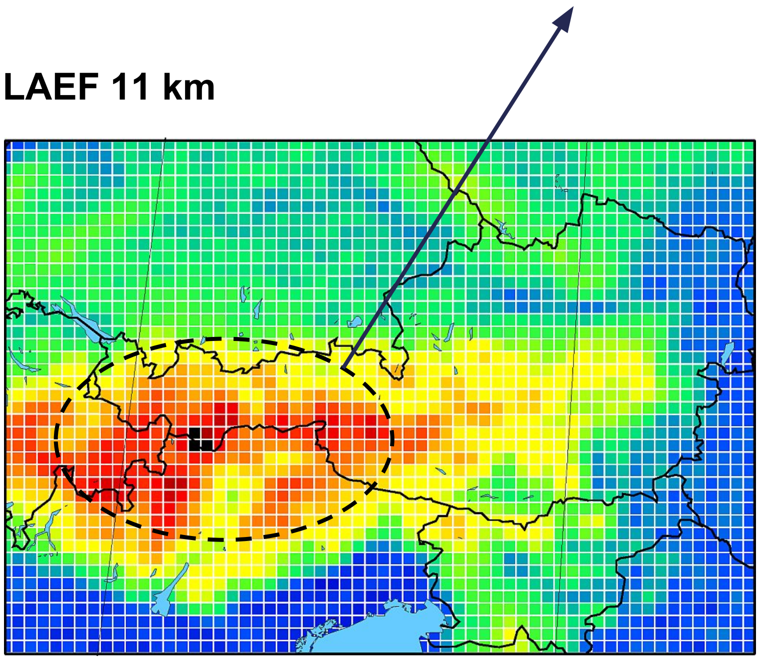


Zoom over Austria *- real grid-box size*

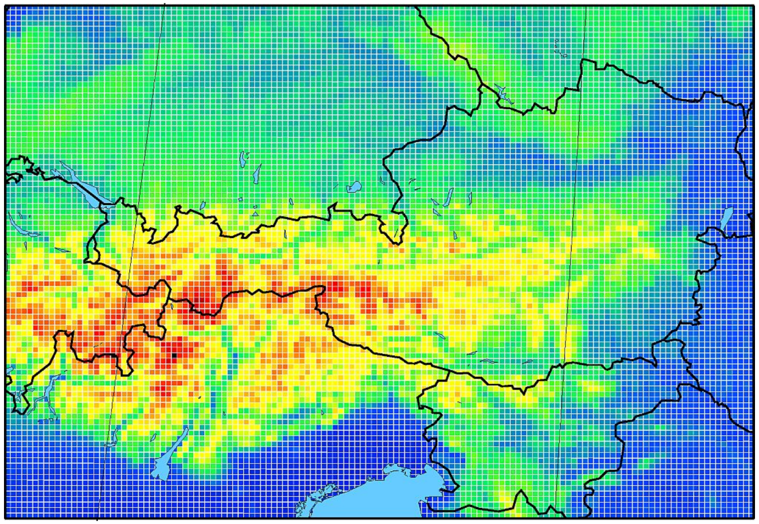
R&D - ALADIN-LAEF 5 km

overestimated height

LAEF 11 km

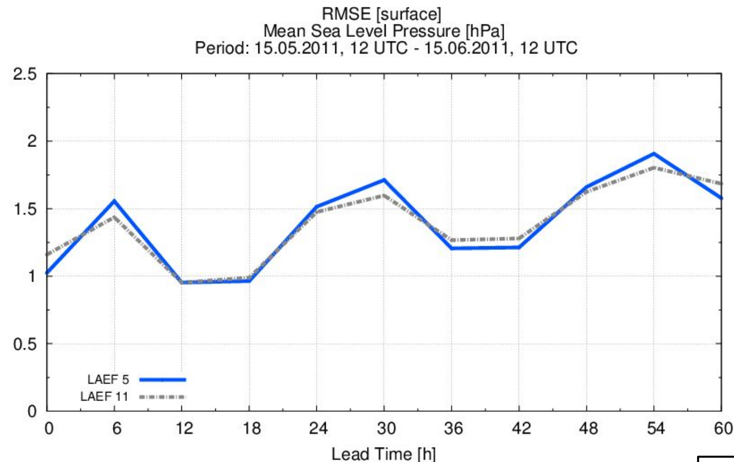


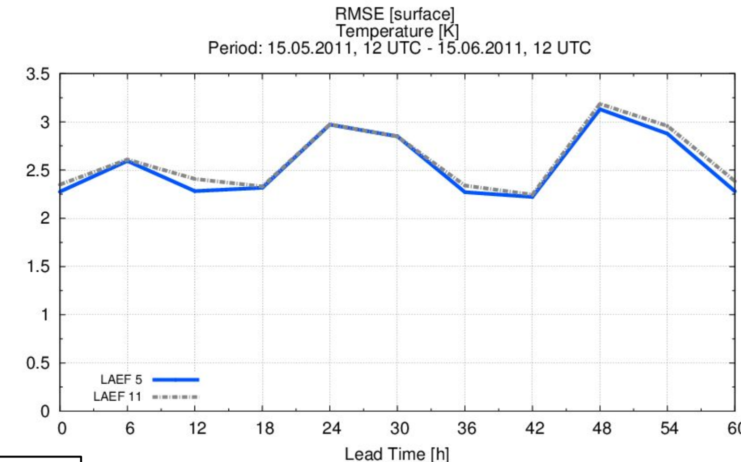
LAEF 5 km



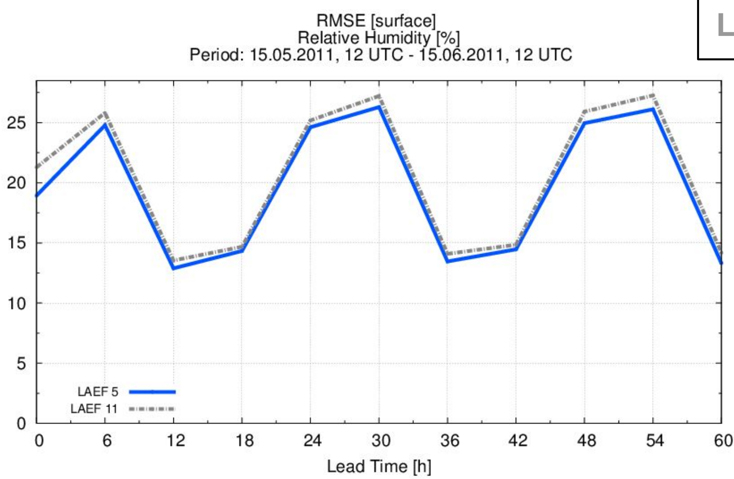
Zoom over Austria *- real grid-box size*

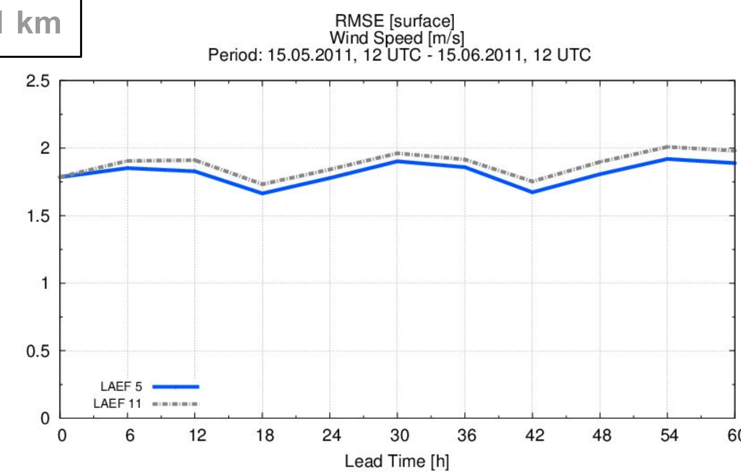
R&D - ALADIN-LAEF 5 km ...verification (RMSE surface)



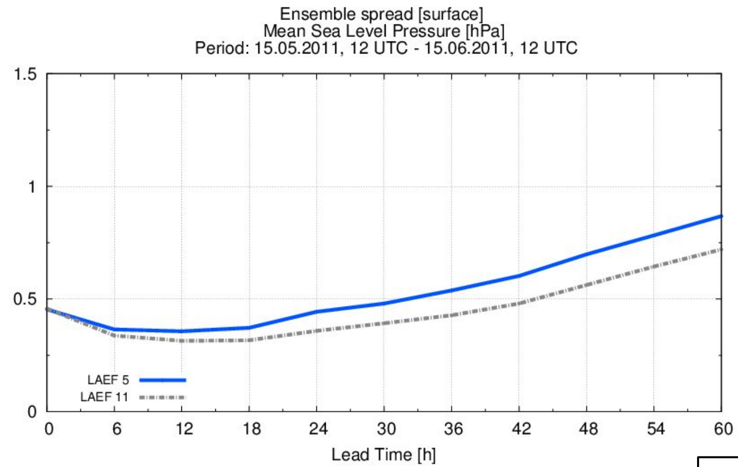


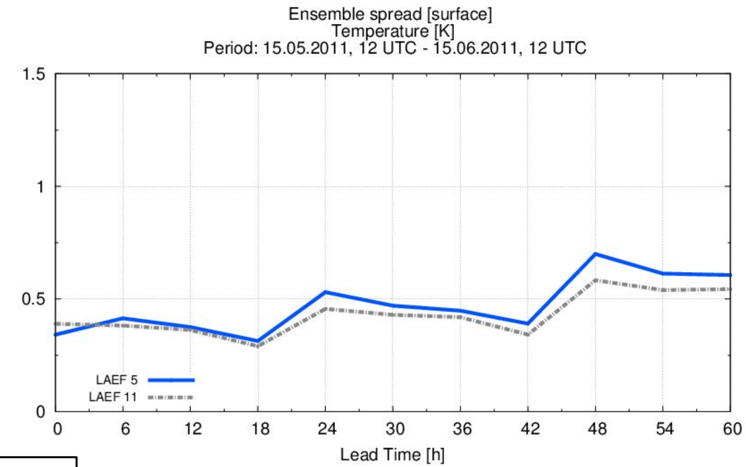
LAEF 5 km
LAEF 11 km



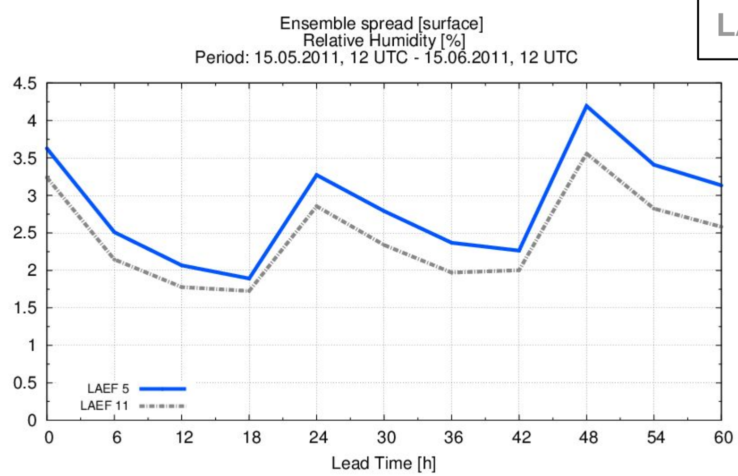


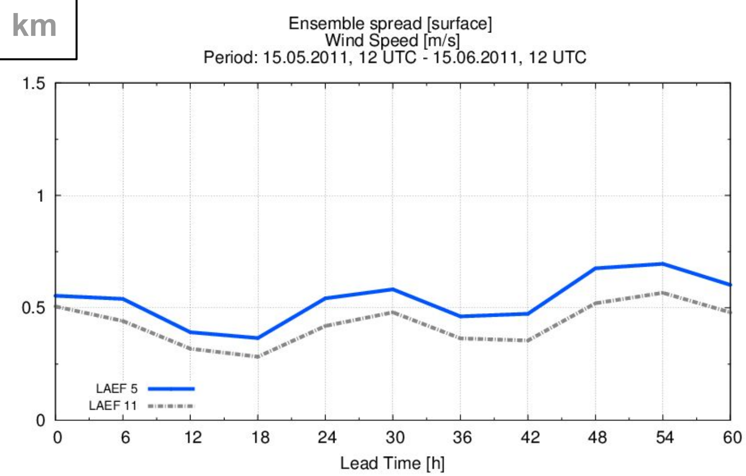
R&D - ALADIN-LAEF 5 km ...verification (SPR. surface)



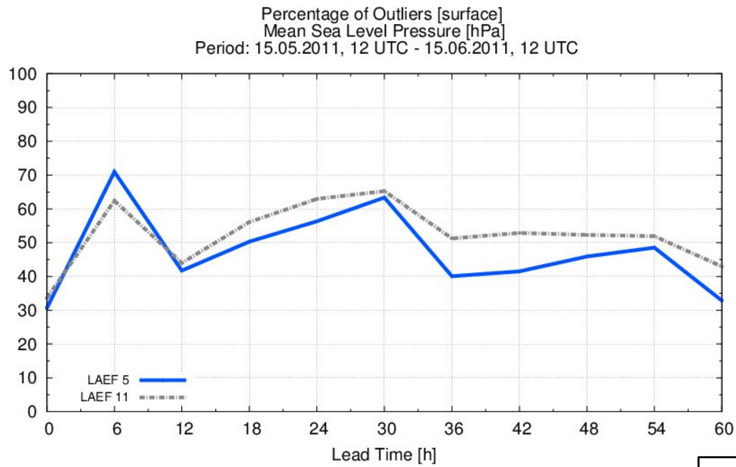


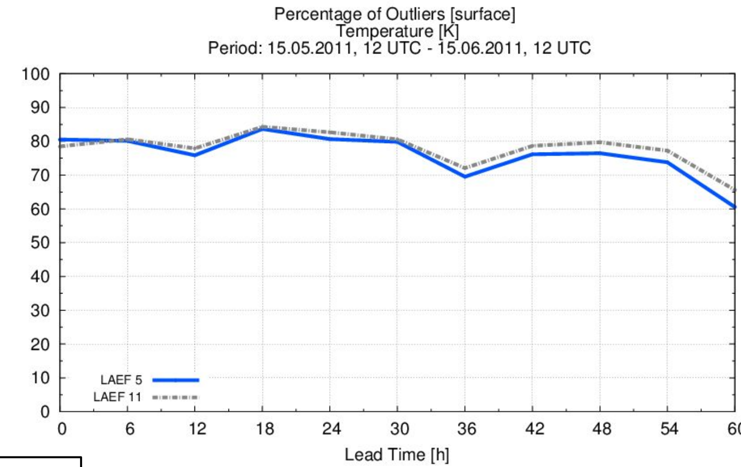
LAEF 5 km
LAEF 11 km



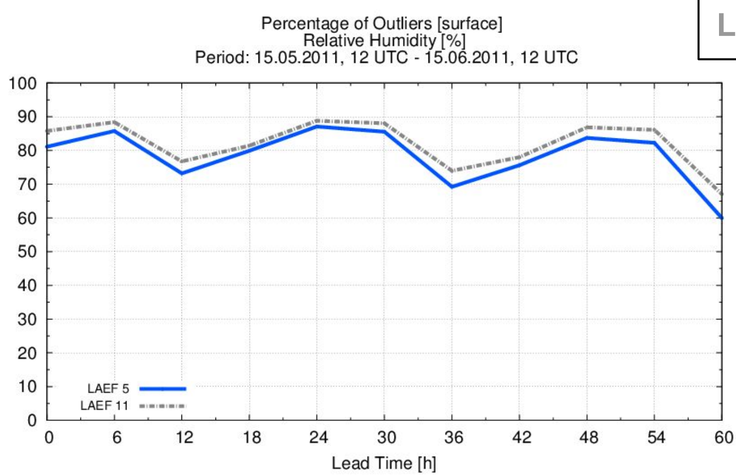


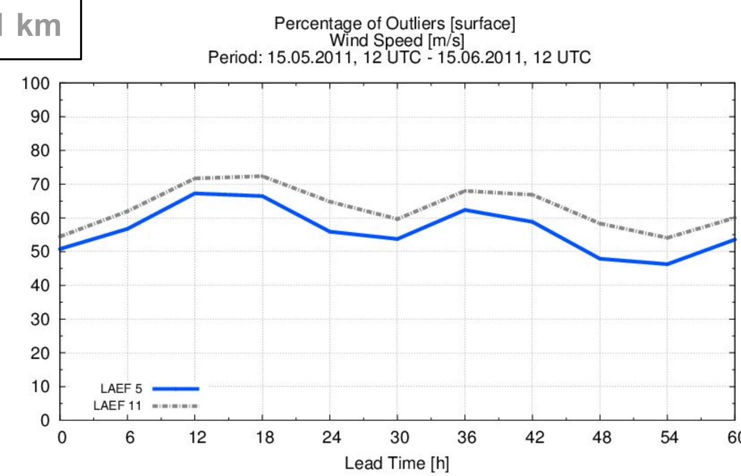
R&D - ALADIN-LAEF 5 km ...verification (OUTL. surface)



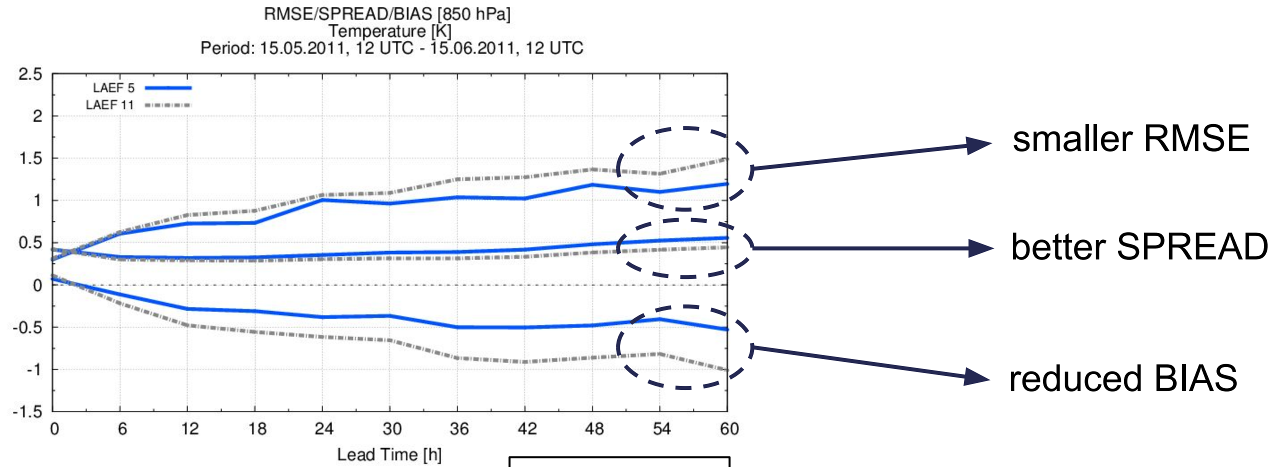


LAEF 5 km
LAEF 11 km

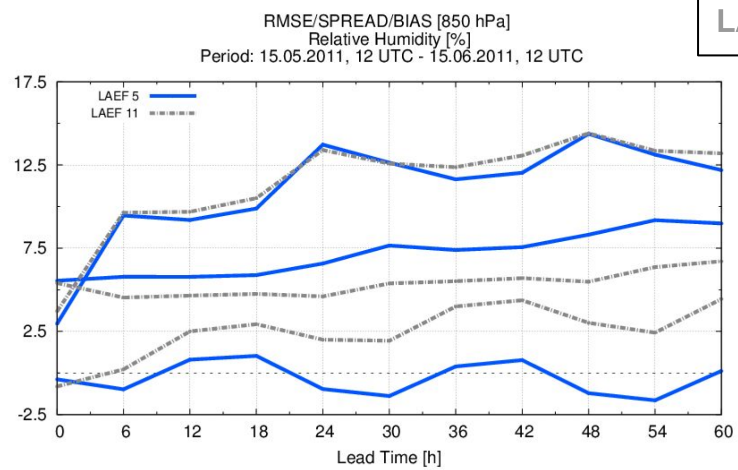


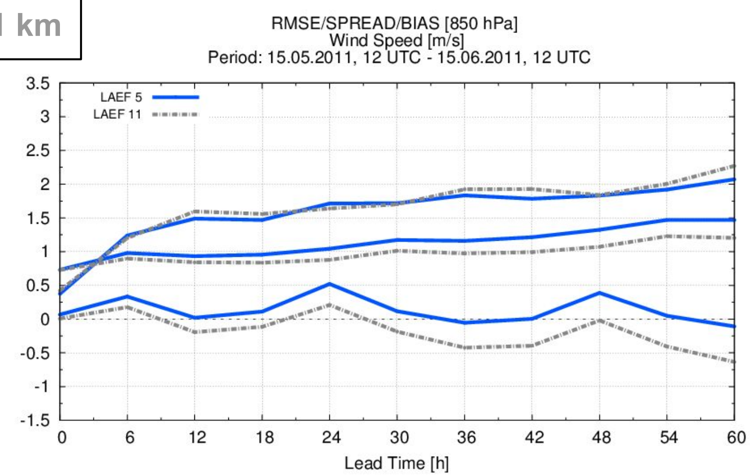


R&D - ALADIN-LAEF 5 km ...verification (850 hPa)



LAEF 5 km
LAEF 11 km





R&D - ALADIN-LAEF 5 km

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- IC uncertainty interpolated
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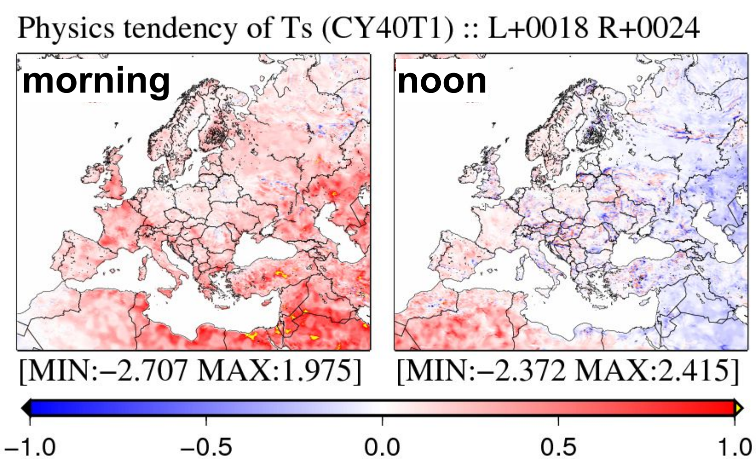
- verified against ALADIN-LAEF 11 km

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?

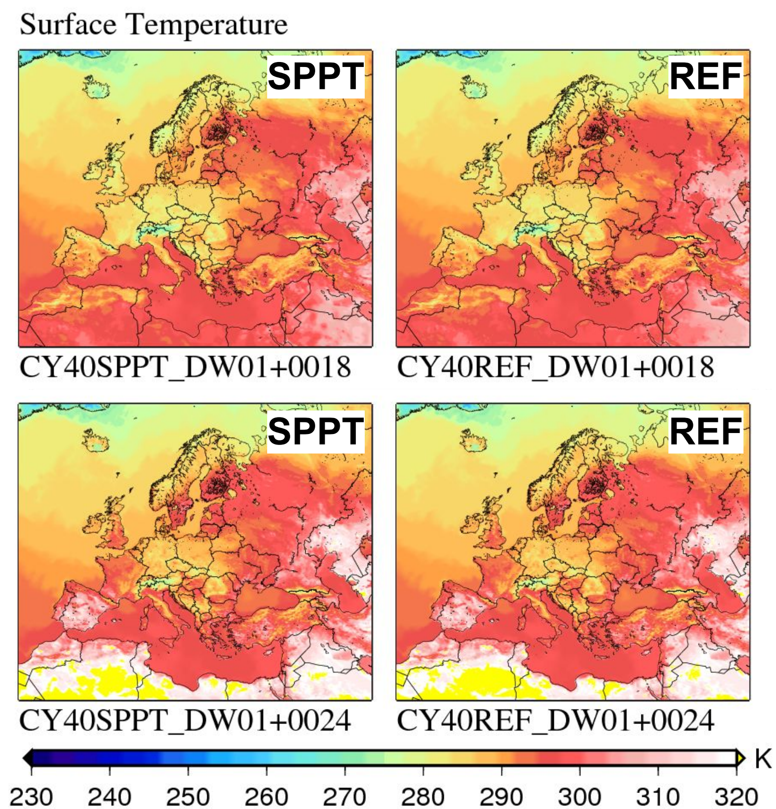
R&D - Stochastic physics in CY40T1 with ALARO-1

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



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

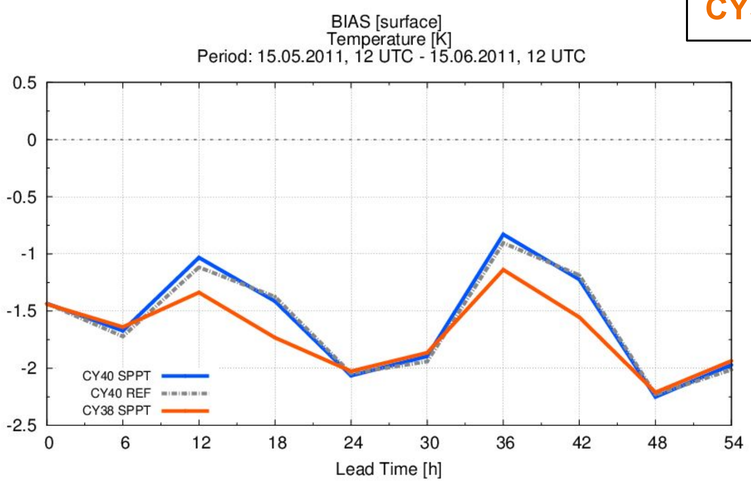
Surface temperature *in bugfixed CY40T1 with SPPT (left) and reference without SPPT (right) for range +18 (morning, up) and +24 (noon, bottom).* →

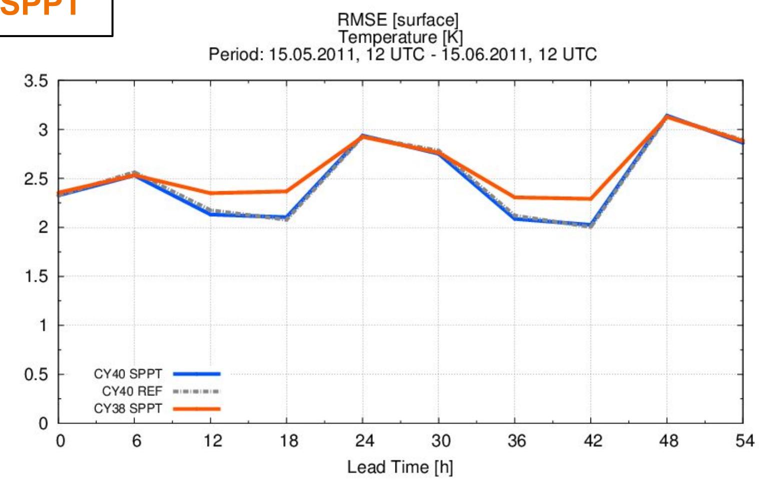


R&D - Stochastic physics in CY40T1 with ALARO-1

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).

CY40 SPPT
CY40 REF
CY38 SPPT





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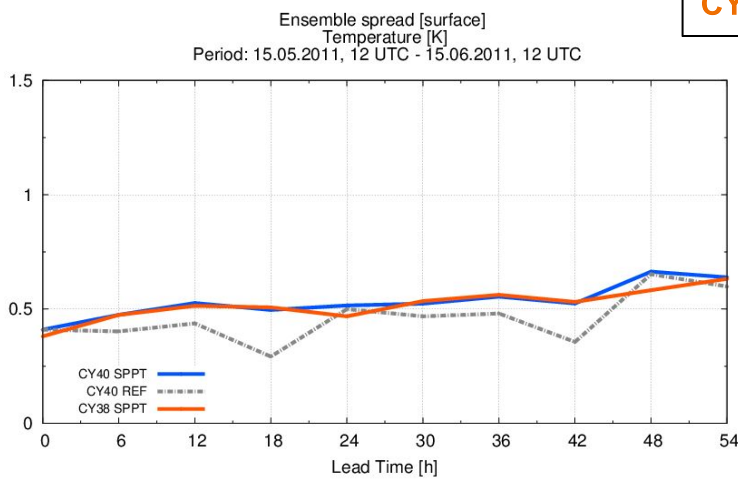
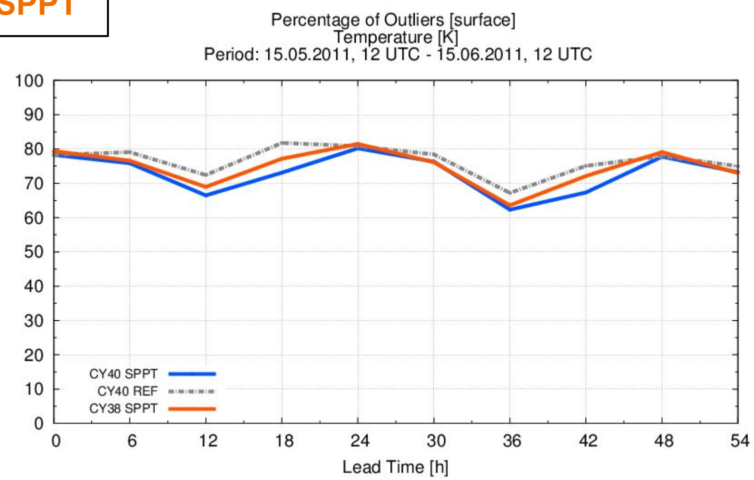
CY40 SPPT
CY40 REF
CY38 SPPT





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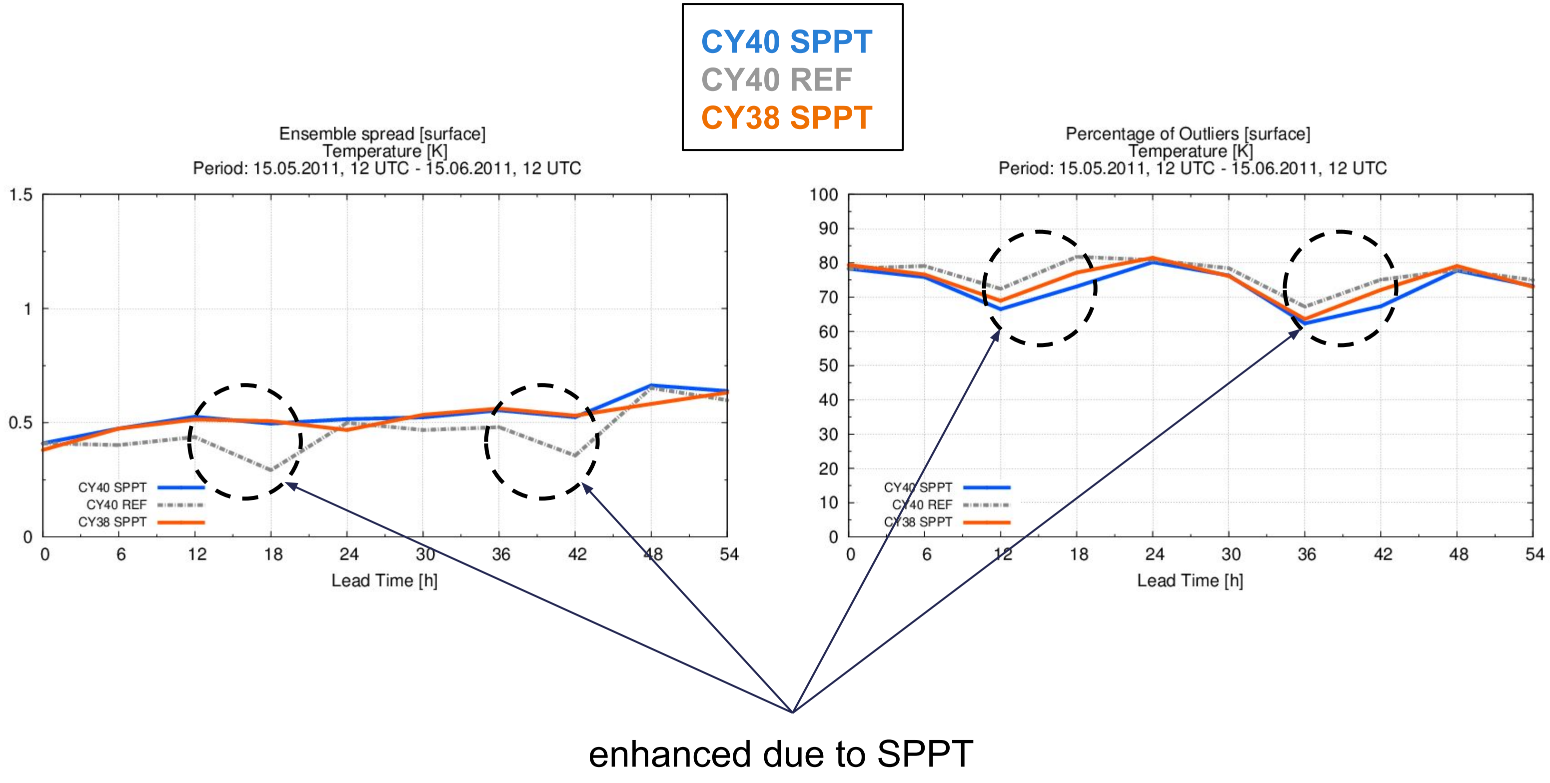


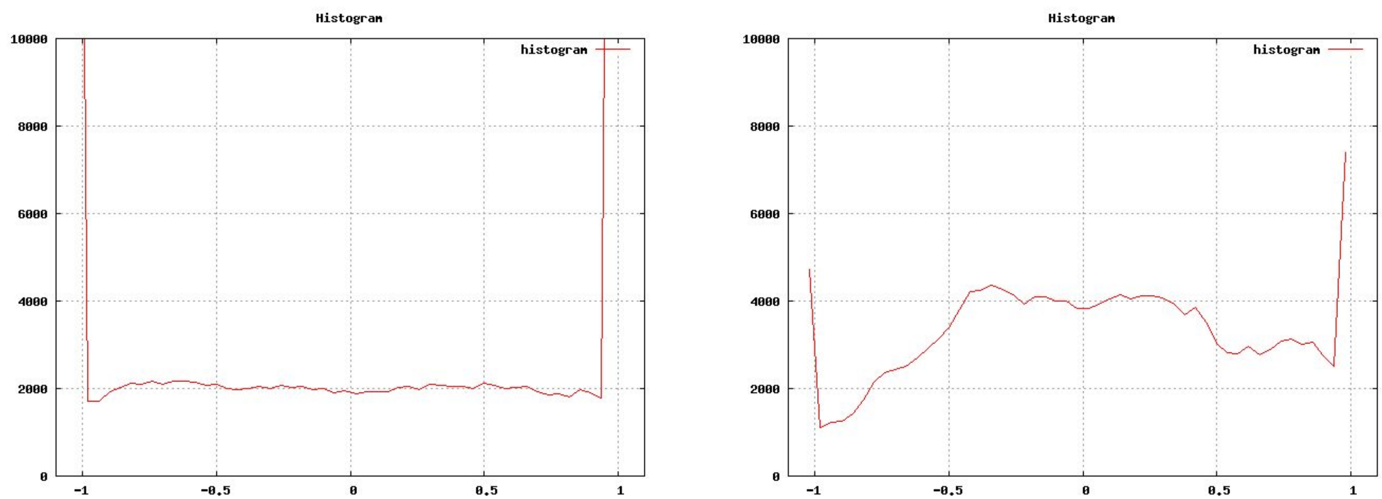
R&D - Stochastic physics (upper-air)

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

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

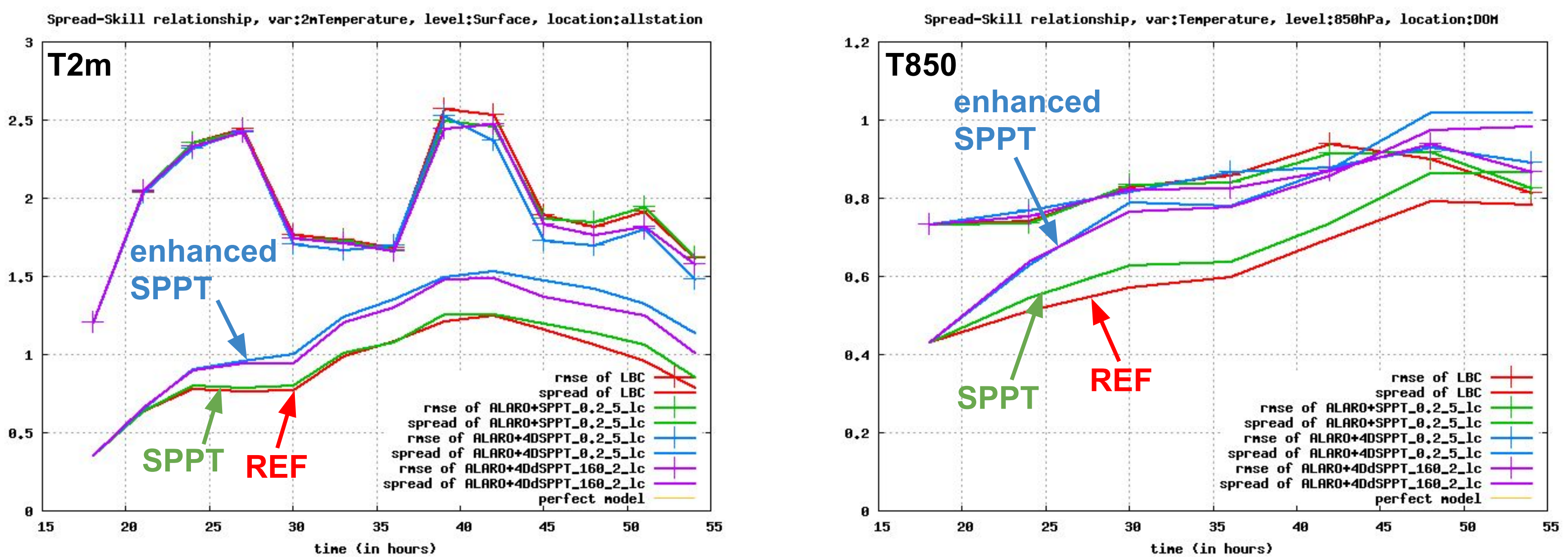
$$P'_{x_j}(\lambda,\varphi,h,t) = \{ 1 + \alpha(h) r_j(\lambda,\varphi,t) \} P_{x_j}$$



*Histogram of **random number values** of the spectral pattern generator for σ=0.5, clipping ratio=2 (left) and for σ=0.25, clipping ratio=4 (right).*

R&D - Stochastic physics (upper-air)

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

- Weidle F., Y. Wang and G. Smet, 2015: "*On the impact of the choice of global ensemble in forcing a regional ensemble system*", Weather and Forecasting, doi: http://dx.doi.org/10.1175/WAF-D-15-0102.1

Submitted papers (currently in review)

- Belluš M., Y. Wang, F. Meier, 2015: "*Perturbing surface initial conditions in a regional ensemble prediction system*", Monthly Weather Review, submitted in January 2016
- Schellander-Gorgas T., Y. Wang, F. Meier, F. Weidle, Ch. Wittmann, A. Kann, 2015: "*On the forecast skills of a convection permitting ensemble*", Weather and Forecasting, submitted in June 2015
- 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!