An overview about the LAMEPS activities in the ALADIN project

András Horányi

Hungarian Meteorological Service

(on behalf of several ALADIN scientists)

Special thanks: ZAMG, DHMZ, Météo France, CHMU, OMSZ

LAMEPS activities at the Hungarian Meteorological Service (HMS)

András HORÁNYI
István IHÁSZ
Sándor KERTÉSZ
Gábor RADNÓTI
Gabriella SZÉPSZÓ
Balázs SZINTAI

Edit HÁGEL
hagel.e@met.hu

Hungarian Meteorological Service

Introduction

An important objective at the Hungarian Meteorological Service (HMS) is to develop a short-range ensemble prediction system which enables us to have a high resolution probabilistic forecast for 2 meter temperature, 10 meter wind and precipitation in the 24-48 hours time range and also to understand and predict better local extreme events like heavy precipitation, wind storms, big temperature anomalies.

At HMS LAMEPS related research started with the downscaling of existing global (i.e. ARPEGE and ECMWF) ensemble systems. Downscaling was performed with the limited area model ALADIN. In case of ARPEGE ensemble forecasts, in addition to the direct downscaling of the operational PEACE system, sensitivity experiments (in terms of singular vector target domain and target time) were also performed. In case of ECMWF ensemble forecast, only the so called (EPS) representative members were downscaled with the ALADIN model. To this end a cluster analysis was performed on the ECMWF ensemble members to select these representative members which were used as initial and lateral boundary conditions for the ALADIN runs.

Description of the global ensemble systems

ECMWF EPS

The ensemble system is running operationally at ECMWF twice a day (at 00 and 12 UTC)

Generation of initial perturbations:

- Initial perturbations are generated by using the singular vector (SV) method
- 25 perturbations are built by the combination of the SVs
- Perturbed initial conditions are created by adding/subtracting the perturbations to/from the unperturbed analysis
- This results in 50 perturbed ensemble members + the control member

Integration:

- Truncation used for integration (at the time of the experiments): T255 (about 80 km)
- Number of vertical levels: 40
- Integration of the 50+1 ensemble members up to 240 hours

The ALADIN domain used in our experiments

The stretched grid of the ARPEGE model

ARPEGE EPS

The ARPEGE EPS system used for our experiments was based on the PEACE (or PEARP) system which is running operationally at Météo-France. The main difference was in the choice of target domain and target time used for the global singular vector computations.

Generation of initial perturbations:

- Initial perturbations are generated by using the singular vector method
- Five perturbations are built by the combination of the first 16 SVs
- Perturbed initial conditions are created by adding/subtracting the perturbations to/from the unperturbed analysis
- This results in 10 perturbed ensemble members + the control member

Main characteristics of the local experiments:

- Five different target domains and
- Two different target times (12 hours and 24 hours) for the global SV computations

Integration:

- Truncation used for integration (at the moment): T358c2.4
- Number of vertical levels: 41
- Integration of the 10+1 ensemble members up to 60 hours

Description of the limited area ensemble system

- Characteristics of the ALADIN model version used in the experiments:
  - Spectral, hydrostatic model
  - Model version AL28T3
  - Dynamical adaptation mode
  - Horizontal resolution: 12 km
  - Number of vertical levels: 37
  - Coupling at every 6 hours
- Initial and lateral boundary conditions from ARPEGE or ECMWF ensemble members
- Integration up to 60 hours in case of ARPEGE/ALADIN ensemble
- Integration up to 84 hours in case of ECMWF/ALADIN ensemble

Sensitivity experiments with the ARPEGE/ALADIN ensemble system

Experiments were performed to investigate the sensitivity of global singular vector computations in terms of target domain and target time. Global (ARPEGE) ensemble members were downscaled with the limited area model ALADIN. The experimentation consisted of individual case studies, 10 days (in summer) and 32 days (in winter) continuous tests.

The five different target domains used for the global SV computations were the following:

- Domain #1: Atlantic Ocean and Western Europe (as in an earlier version of PEACE)
- Domain #2: Atlantic Ocean and Western Europe (as in the present PEACE system)
- Domain #3: Europe and some of the Atlantic Ocean
- Domain #4: nearly whole Europe
- Domain #5: a slightly bigger area than Hungary

The five different target domains. Black: domain #1, blue: domain #2, green: domain #3, orange: domain #4, red: domain #5.

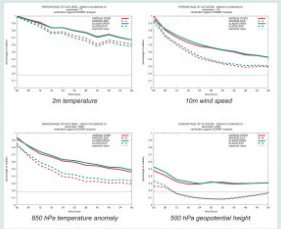
Two different target times were used: 12 hours (as in the PEACE system) and 24 hours.

Results

Based on the results of the case studies and the 10 days continuous test it was decided to perform a longer (~30 days) experiment. On the one hand the operational PEACE members were downscaled with the ALADIN model, and on the other hand an experimental ARPEGE ensemble system was built. The only difference between this experimental system and PEACE was in the choice of SV target domain and target time. As target domain domain #3 was used (see the picture above), the target time was chosen as 24 hours. In the PEACE system domain #2 is used as SV target domain and the target time is 12 hours. The experimental set was also downscaled with the ALADIN model.

For the objective evaluation Talagrand, ROC and reliability diagrams were plotted, the BIAS and RMSE values of the ensemble mean and the control forecast were computed for both ARPEGE and ALADIN respectively.

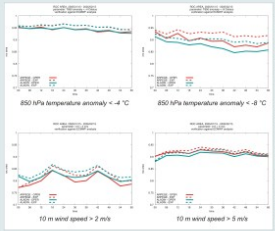
Percentage of outliers diagrams for the ARPEGE and ALADIN ensemble systems for the period 2005/01/15 - 2005/02/15 for 2 meter temperature, 10 meter wind speed, 850 hPa temperature anomaly and 500 hPa geopotential height. The solid red line is the operational PEACE forecast, dashed red line is the experimental ARPEGE ensemble (with modified SV target domain and target time), solid green line is ALADIN coupled with the operational PEACE members and dashed green line is ALADIN coupled with the experiemental set. (In the ideal case the percentage of outliers is equal to 2*1/(ensemble members+1), which is around 0.2 for our system.)



2m temperature | *10m wind speed* | *850 hPa temperature anomaly* | *500 hPa geopotential height*

It was found that the change of the target domain and target time during the global SV computation could improve the system's ability to comprise the true state of the atmosphere. Looking at the percentage of outliers clear improvement can be seen especially for upper level parameters.

However, it is also clear that the simple downscaling of the global ensemble system with the ALADIN model does not yield significant improvements. For some parameters the ALADIN forecasts have better scores (e.g. 2 meter temperature), for others (e.g. 850 hPa temperature) the ARPEGE ones.



850 hPa temperature anomaly < -4 °C | *850 hPa temperature anomaly < -8 °C* | *10 m wind speed > 2 m/s* | *10 m wind speed > 5 m/s*

ROC area diagrams for the ARPEGE and ALADIN ensemble systems for the period 2005/01/15 - 2005/02/15 for 850 hPa temperature anomaly and 10 meter wind speed. The solid red line is the operational PEACE forecast, dashed red line is the experimental ARPEGE ensemble (with modified SV target domain and target time), solid green line is ALADIN coupled with the operational PEACE members and dashed green line is ALADIN coupled with the experiemental set. (The value 1 represents perfect forecast, while a value less than 0.5 means the forecast has no skill compared to the use of climatological statistics.)

Changing the target domain and target time used for the global SV computations yields improvement for the 850 hPa temperature anomaly. The ROC area shows rather good scores for the -4°C threshold (without loss of quality with the integration time), however the relative improvement is higher for the -8°C threshold value. (The examined period was much colder than the average therefore the scores for T850 temperature anomaly higher than +4°C and +8°C are not shown.)

For the 10 meter wind speed the improvement is less significant compared to the 850 hPa temperature anomaly. However, the change of the target domain and target time yields clear improvement for this parameter as well. It is important to note that the quality of the ensemble system increases for stronger wind values which is an encouraging result, especially if one would like to represent correctly extreme events.

The conclusions of the systematic comparison between ARPEGE and ALADIN ensemble systems indicate that the direct downscaling of the ARPEGE ensemble system is not sufficient to obtain a good, high resolution limited area ensemble system: there is a strong need to develop such methods, which are properly and directly accounting for the mesoscale uncertainties in the initial conditions of the ALADIN model. At the same time research should be pursued towards the consideration of other sources of uncertainties in the limited area models (e.g. deficiencies in the description of the parameterized processes) as well.

Downscaling of ECMWF ensemble forecasts, the ECMWF/ALADIN ensemble system

Encouraged by the success of COSMO-LEPS a set of experiments was launched with the downscaling of ECMWF ensemble forecasts. The system used in the experiments consists of the following steps:

- Cluster analysis on the ECMWF ensemble members resulting 10 clusters
- Selection of representative members (RMs) from each cluster
- Downscaling of the 10 RMs using the limited area model ALADIN

The system has two main parts:

- The clustering:
  - Hierarchical clustering method
  - Four meteorological parameters (geopotential, relative humidity, two wind components) on three isobaric levels (500, 700 and 850hPa)
  - Two clustering times
  - The clustering was tested on two different clustering domains
  - The clustering of 50 and 100 members was also tested (members of one EPS run or members of two consecutive EPS runs)
- The ALADIN runs
  - Initial and lateral boundary conditions provided by the 10 ECMWF RMs
  - Integration up to 84h

The two clustering domains of the ECMWF/ALADIN ensemble system. (The bigger clustering area is the same as the integration domain of the ALADIN model)

Shematic description of the clustering time while using 100 ECMWF EPS members

Description of the experiments

The ECMWF/ALADIN ensemble system was tested on four configurations which differ from each other only in the parameters of the clustering method, the ALADIN runs had the same settings:

- Clustering on the bigger domain, using one set of ECMWF EPS (50 members)
- Clustering on the smaller domain, using one set of ECMWF EPS (50 members)
- Clustering on the bigger domain, using two sets of ECMWF EPS (100 members)
- Clustering on the smaller domain, using two sets of ECMWF EPS (100 members)

When using only one set of ECMWF EPS (50 members) the 12 UTC EPS run was used. When using two sets of ECMWF EPS (100 members) the 00 UTC and the 12 UTC EPS runs of the same day were joined. The clustering times were +60 hours and +84 hours for the 12 UTC EPS and +72 and +96 hours for the 00 UTC EPS.

Results

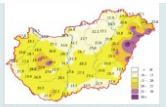
So far four case studies have been performed. All of these cases were related to precipitation events. In three cases the ECMWF EPS underestimated the precipitation, while in the fourth one the precipitation was rather overestimated. The subjective verification on the one hand showed that the downscaling improved the quality of the forecasts compared with the global ones by decreasing the precipitation underestimation (in the first three cases) and on the other hand proved that the system is capable to make a correction in case of events corresponding to global precipitation overestimation (fourth case).

Based on the first evaluation results it can be outlined that (in the limited number of examined cases) the ECMWF/ALADIN downscaling system could bring benefit on top of the global ECMWF EPS system. However, the results should be further assessed and confirmed by a more detailed experimentation.

Observed precipitation values (mm) between 2005/05/18 06 UTC and 2005/05/19 06 UTC.

Case study - 18 May 2005

On 18 May, 2005 a squall line passed through Hungary causing heavy precipitation and strong wind gusts all over the country. Because of the favorable conditions for convection supercells formed both in the western and eastern part of the country. The 24 hours accumulated precipitation exceeded 30 mm at several areas. This event was investigated with both the ECMWF/ALADIN and the ARPEGE/ALADIN limited area ensemble systems.

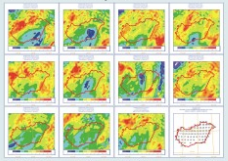


Maximal observed wind gust values (m/s) between 2005/05/18 00 UTC and 2005/05/19 00 UTC.

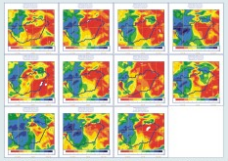
In this case the ECMWF EPS significantly underestimated the amount of precipitation (not shown). At the same time the ALADIN ensemble forecast indicated higher amounts (however the underestimation still exists at some ensemble members mainly in the north-eastern part of the country). It should be mentioned that not only the fine scale details had been modified by the higher resolution system, but also some of the structures in the precipitation patterns which indicates that not only the increased resolution but also the dynamics and physics of the ALADIN model played an important role in the downscaling process.

The maximum wind gust also reached high values at several parts of the country. In the ECMWF EPS the maximal wind gust was pretty much underestimated (not shown). Downscaling with the ALADIN model resulted in significant improvements in the forecast of wind gust. Some members even forecasted correctly the maximal values in the eastern part of the country.

ECMWF/ALADIN ensemble system

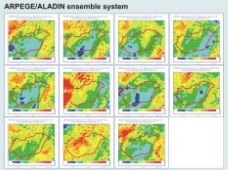


ECMWF/ALADIN ensemble forecasts of the 24 hours precipitation for the period 2005/05/18 06 UTC - 2005/05/19 06 UTC. Forecast started at 2005/05/16 12 UTC. The third panel in the bottom row is the downscaling of the control forecast of ECMWF EPS. The fourth panel in the same row shows the observed precipitation values.

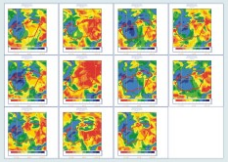


ECMWF/ALADIN ensemble forecasts of the maximal wind gust for the period 2005/05/18 00 UTC - 2005/05/19 00 UTC. Forecast started at 2005/05/16 12 UTC. The third panel in the bottom row is the downscaling of the control forecast of ECMWF EPS.

ARPEGE/ALADIN ensemble system



ARPEGE/ALADIN ensemble forecasts of the 24 hours precipitation for the period 2005/05/18 06 UTC - 2005/05/19 06 UTC. Forecast started at 2005/05/16 18 UTC. The first panel in the top row is the downscaling of the control member of the ARPEGE EPS (PEACE).



ARPEGE/ALADIN ensemble forecasts of the maximal wind gust for the period 2005/05/18 00 UTC - 2005/05/19 00 UTC. Forecast started at 2005/05/16 18 UTC. The first panel in the top row is the downscaling of the control member of the ARPEGE EPS (PEACE).

Comparing the results of the two different limited area ensemble systems (ECMWF/ALADIN, ARPEGE/ALADIN) one can realise that they differ pretty much in the forecast of precipitation, while the wind gust forecasts are quite similar. Therefore it seems that in the case of precipitation the initial and lateral boundary conditions play an important role, while in the case of wind gust it is the limited area model itself which determines the quality of the forecast.

Conclusion and future plans

Verification results of the ARPEGE/ALADIN ensemble system show that the proper choice of the SV target domain and target time can increase the spread and (on average) improve the the skill of the ensemble system for the Central European area. On the other hand the studied limited area ensemble system was found not to provide significant additional information with respect to the global one, therefore the computation of mesoscale initial perturbations for the limited area model might be desirable for a more efficient short-range ensemble system. The work with singular vectors computed with the limited area model ALADIN has already started.

As for the ECMWF/ALADIN ensemble system it was found that (in the examined cases) the ALADIN model was able to bring benefit on top of the global ECMWF EPS. Of course, these first results should be further assessed and confirmed by a more detailed experimentation of the downscaling system.

Acknowledgement

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  - ARPEGE EPS: PEACE (PEARP) AND ITS DOWNSCALING
  - ECMWF/IFS EPS DOWNSCALING
- COMPUTATION OF MESOSCALE PERTURBATIONS:
  - BREEDING
  - COMPUTATION OF SINGULAR VECTORS
- ADDITIONAL AVAILABLE LAMEPS SYSTEMS: SRNWP-PEPS, COSMO-LEPS
- COOPERATION WITH HIRLAM

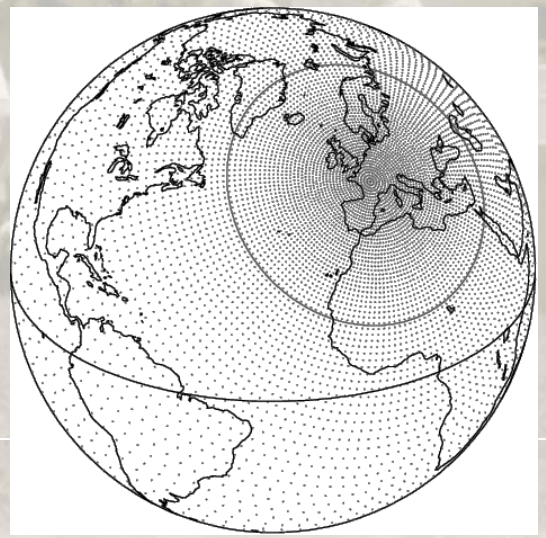
WHAT IS NOT MENTIONED?

- UNCERTAINTIES IN MODEL PHYSICS
- LBC PERTURBATIONS
- INTER-RELATION BETWEEN DATA ASSIMILATION AND EPS (e.g. ETKF)
- CALIBRATION, POST-PROCESSING AND VERIFICATION

SHORT RANGE ENSEMBLE SYSTEM BASED ON PEACE-PEARP (France, Czech Republic, Hungary)

GLOBAL SHORT RANGE EPS AT METEO FRANCE

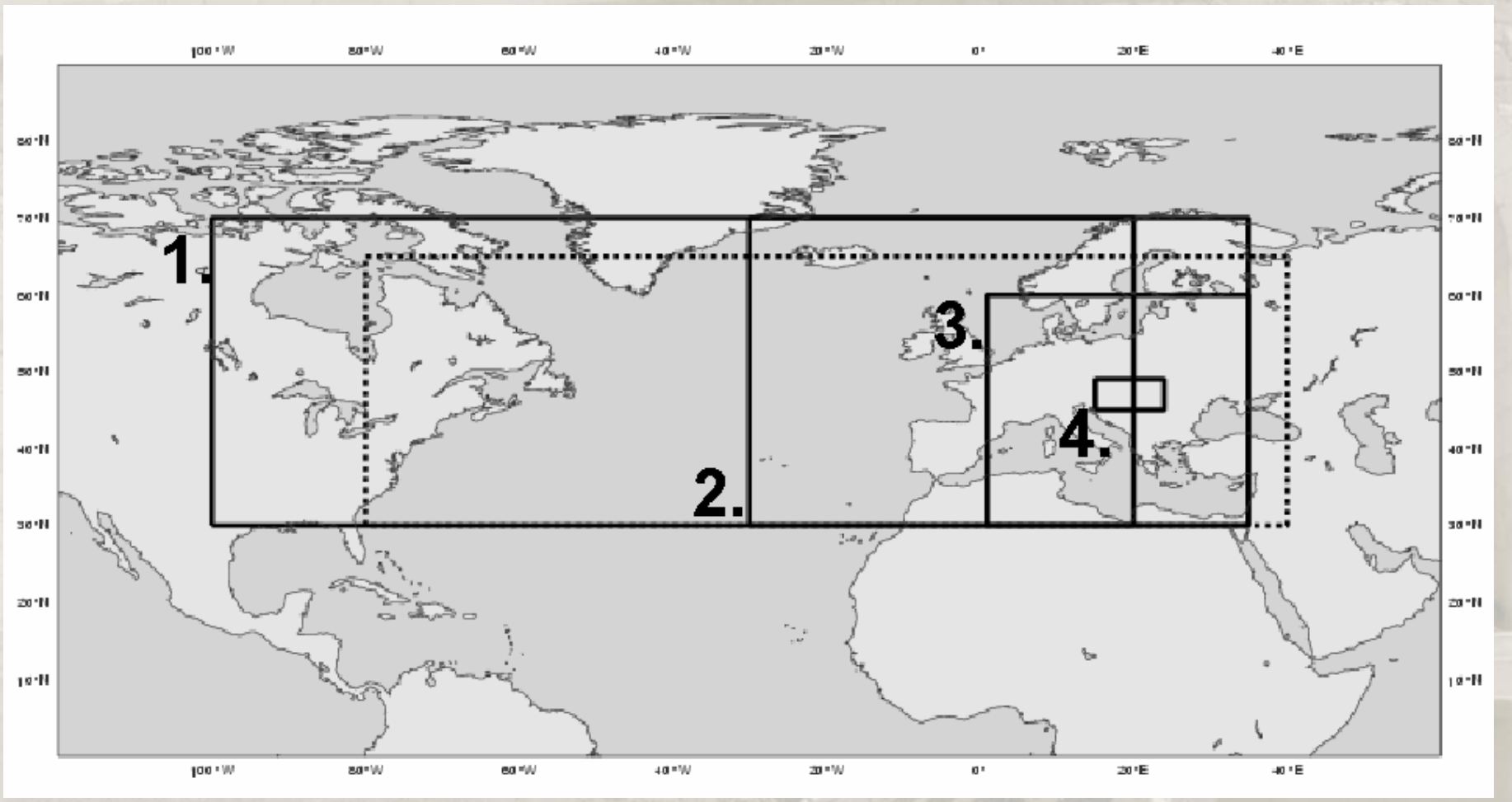
- PEACE/PEARP operational system
  - ARPEGE based short range ensemble system
  - Computation of initial perturbations by singular vectors
  - Orthogonal perturbations obtained through the linear combination of the first 16 singular vectors
  - Norm: total energy norm (initial and final time)
  - 10 + 1 members
  - 60 hours integration



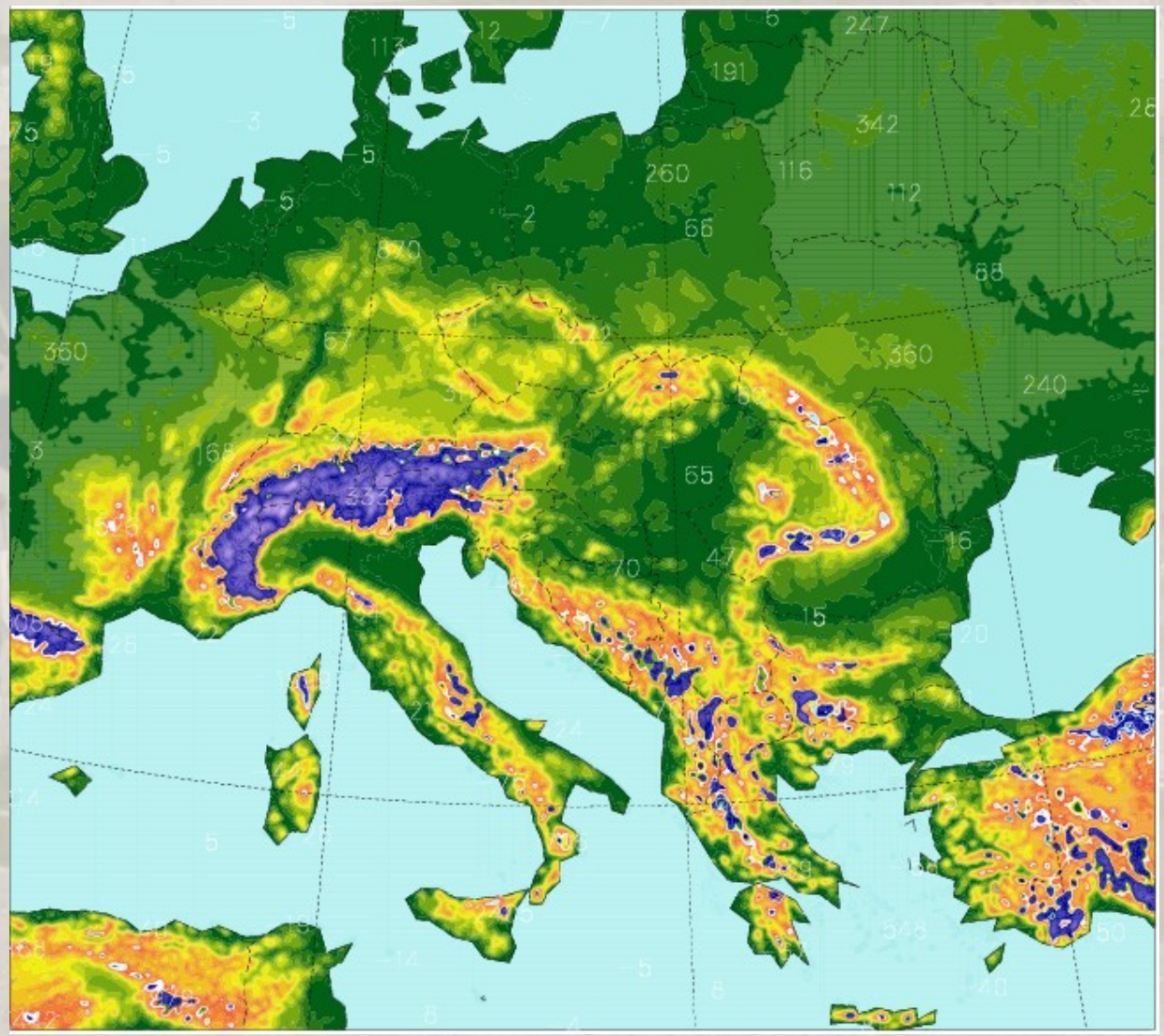
SENSITIVITY OF GLOBAL SINGULAR VECTORS WITH RESPECT TO TARGET DOMAIN AND OPTIMIZATION TIME

- Target domains: 5 domains (see figure)
- Optimisation time: 12h and 24h
- Downscaling with the ALADIN model (European domain, 12 km horizontal and 37 levels vertical resolution)

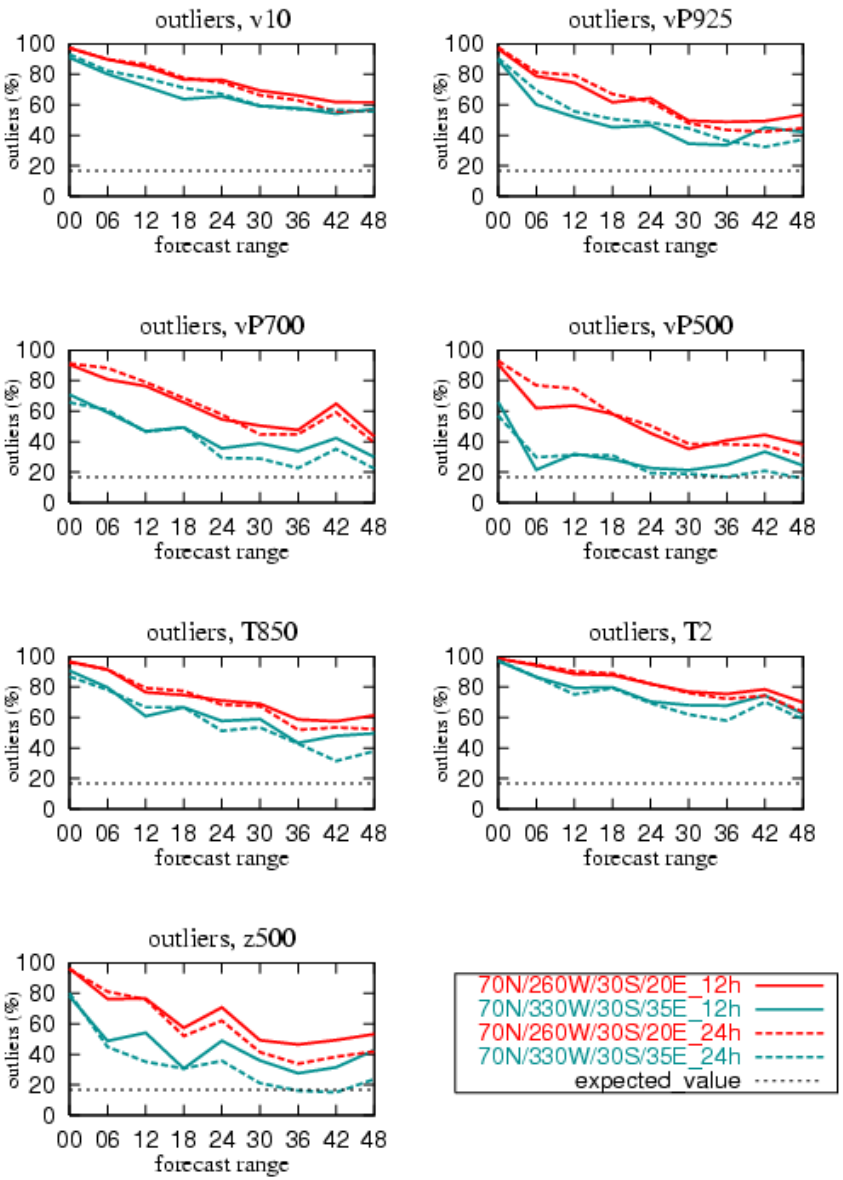
LAMEPS activities in ALADIN: overview



LAMEPS activities in ALADIN: overview

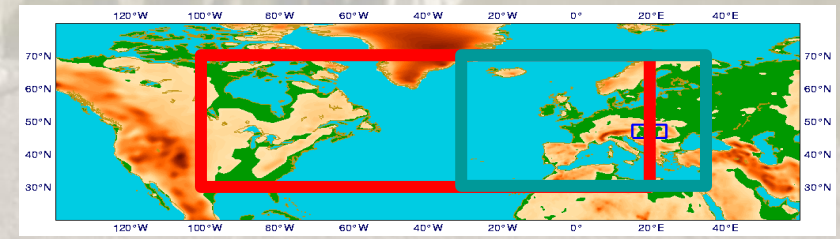


SENSITIVITY OF GLOBAL SINGULAR VECTOR COMPUTATION

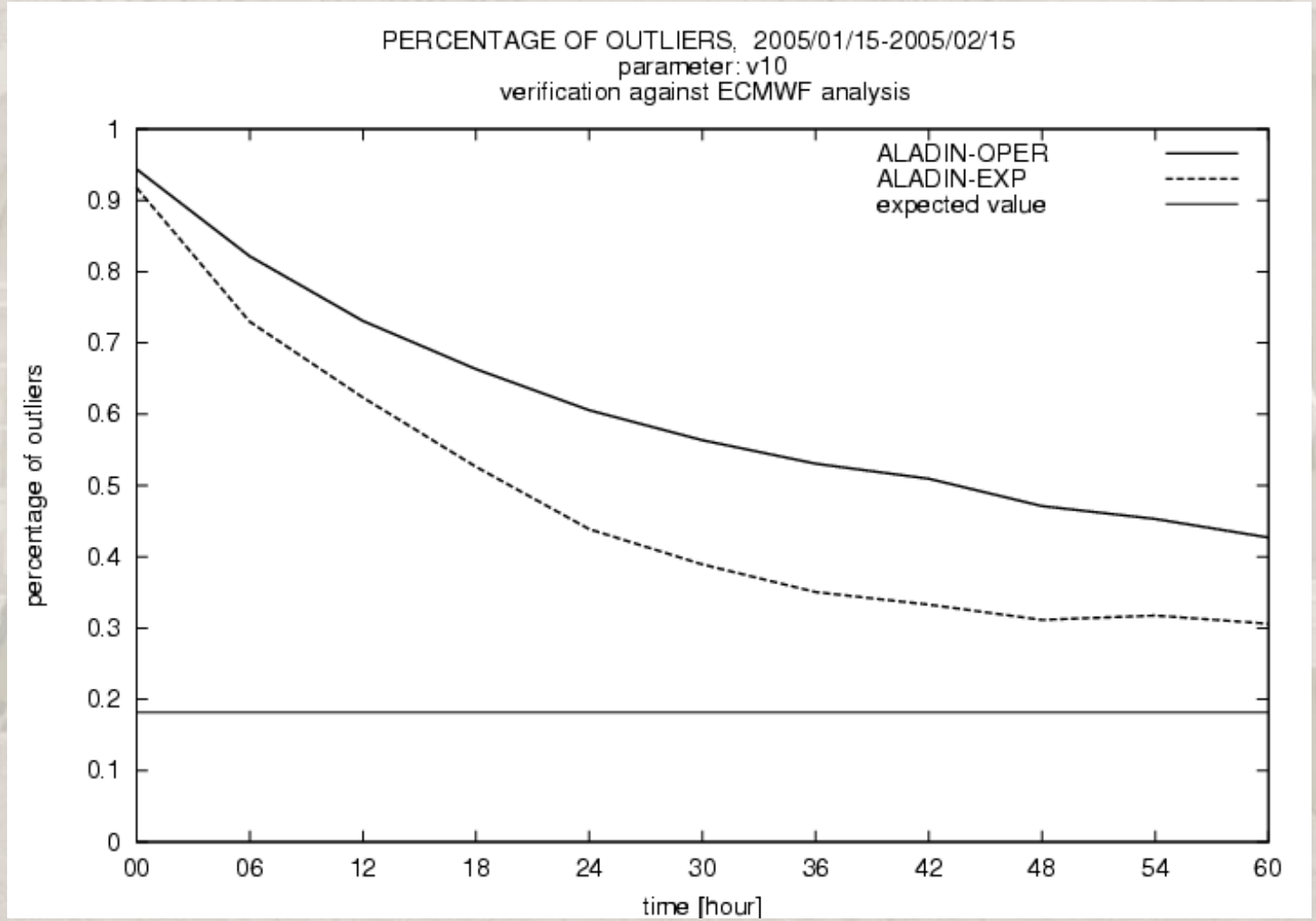


- Target domain 1.)
- target time: 12h
- target time: 24h

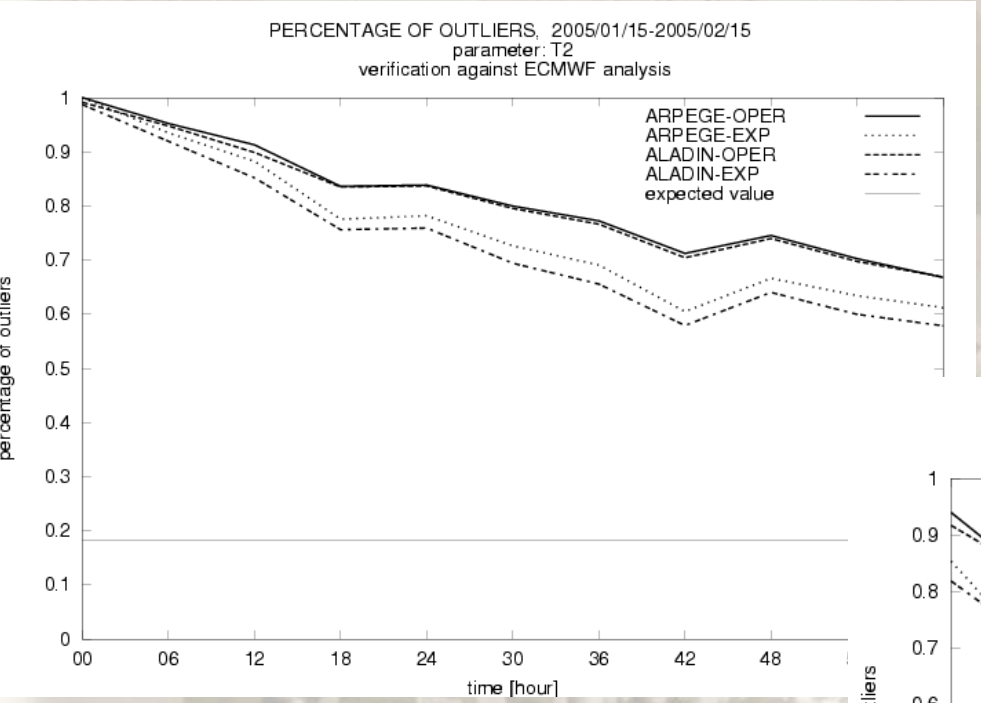
- Target domain 2.)
- target time: 12h
- target time: 24h

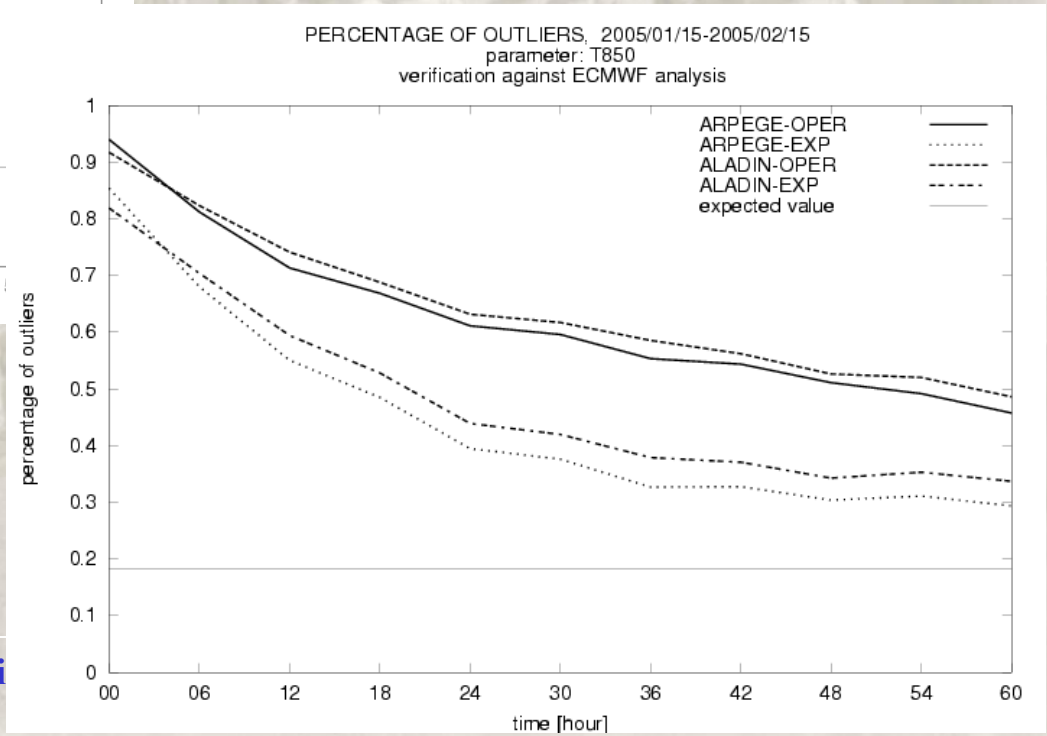


PEACE DOWNSCALING: ALADIN



GLOBAL vs. LAM EPS



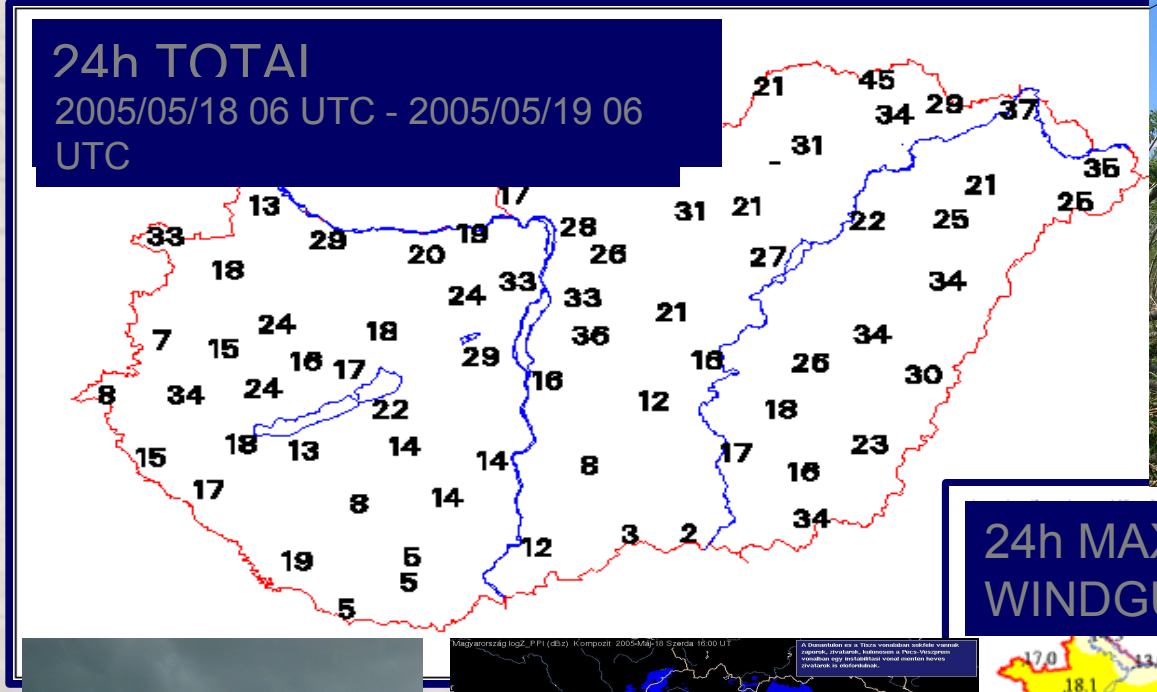


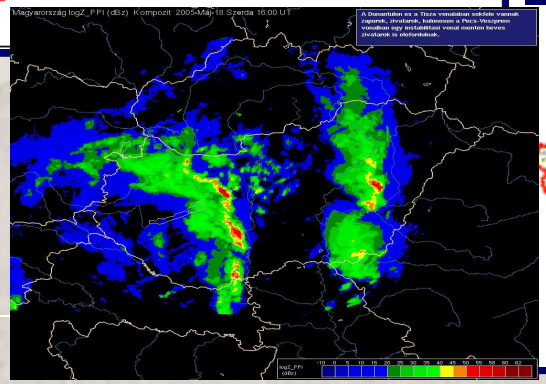
DIRECT DOWNSCALING OF ECMWF/IFS ENSEMBLE PREDICTION SYSTEM (Croatia, Hungary)

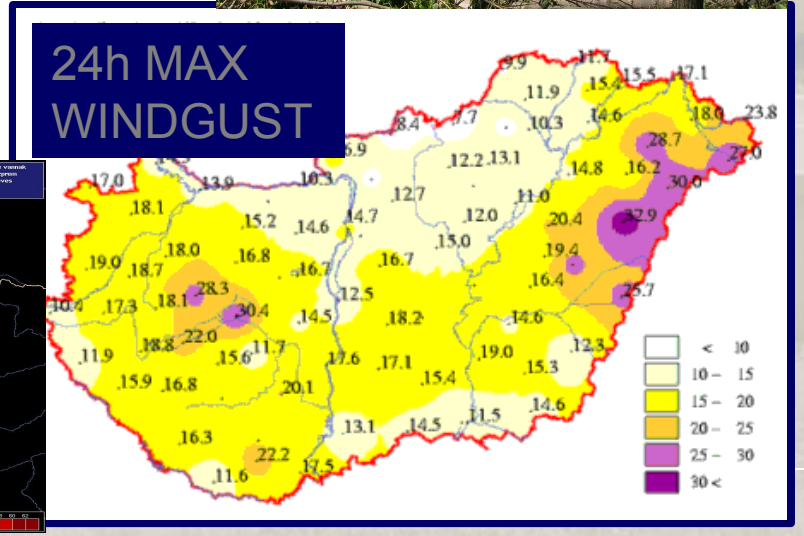
DOWNSCALING OF ECMWF/IFS EPS

- ECMWF EPS system
  - IFS based medium range ensemble system
  - 50 + 1 members
  - 10 days integration
- Clustering of ECMWF EPS
  - 10 clusters with representative members from 51 and then 102 EPS members
  - Clustering at +60h and +84h
- ALADIN integration
  - 84 hours forecasts
- Verification
  - Case studies (precipitation events)

CASE STUDY: 18th of MAY, 2005 (cold front + supercell) OBSERVATIONS







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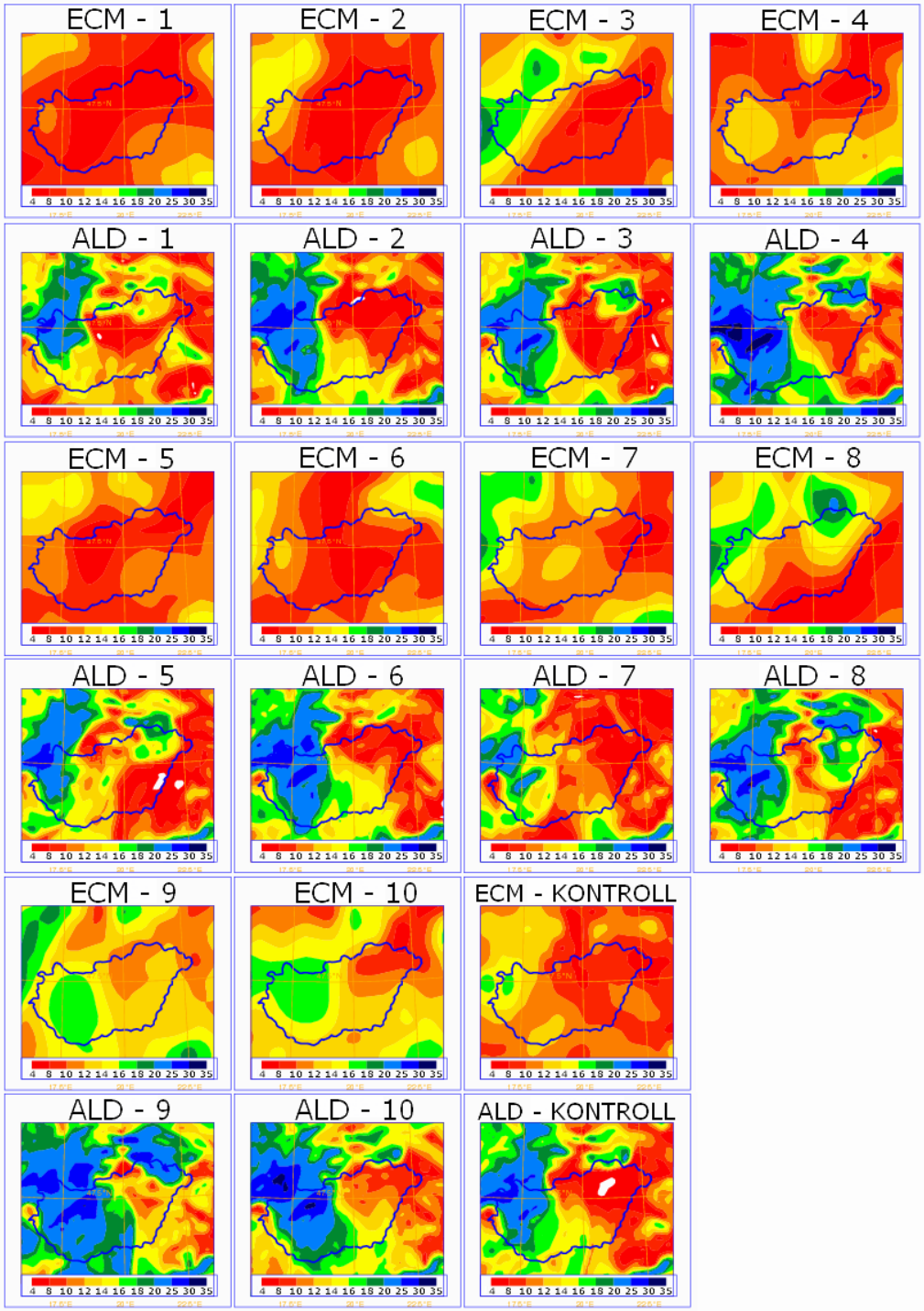
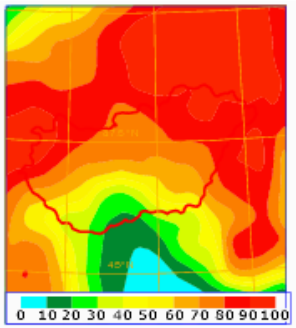
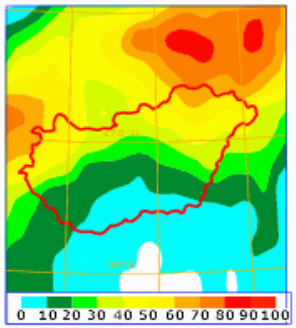

ECM - 1
ECM - 2
ECM - 3
ECM - 4
ALD - 1
ALD - 2
ALD - 3
ALD - 4
ECM - 5
ECM - 6
ECM - 7
ECM - 8
ALD - 5
ALD - 6
ALD - 7
ALD - 8
ECM - 9
ECM - 10
ECM - KONTROLL
ALD - 9
ALD - 10
ALD - KONTROLL
4 8 10 12 14 16 18 20 25 30 35

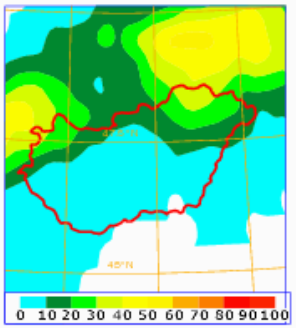
ECMWF - 50
10 mm



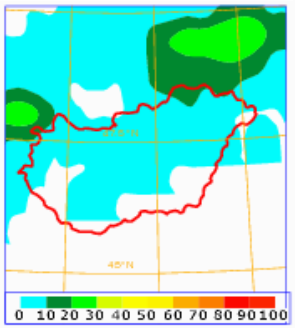
ECMWF - 50
20 mm



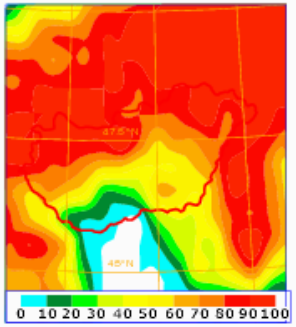
ECMWF - 50
30 mm



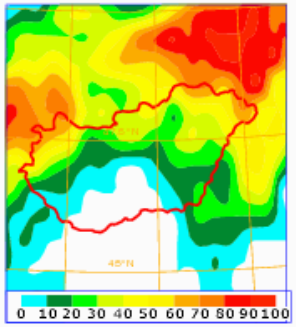
ECMWF - 50
40 mm



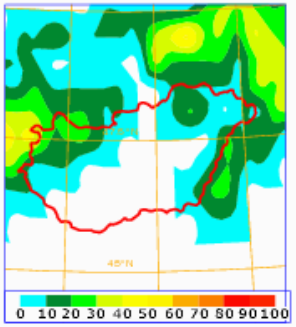
ECMWF - 10
10 mm



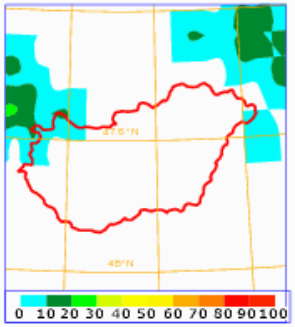
ECMWF - 10
20 mm



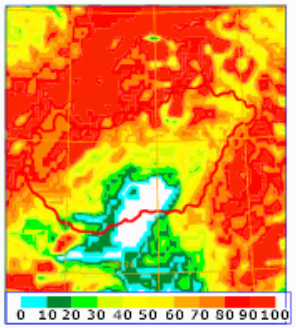
ECMWF - 10
30 mm



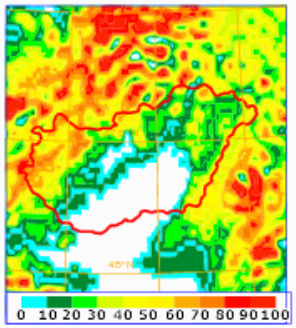
ECMWF - 10
40 mm



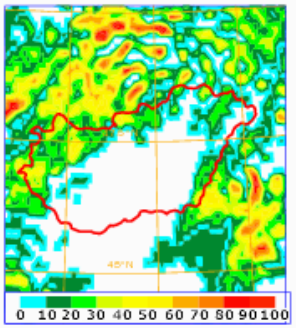
ECMWF/ALADIN
10 mm



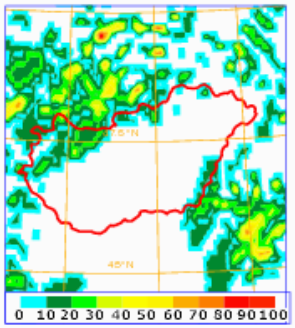
ECMWF/ALADIN
20 mm



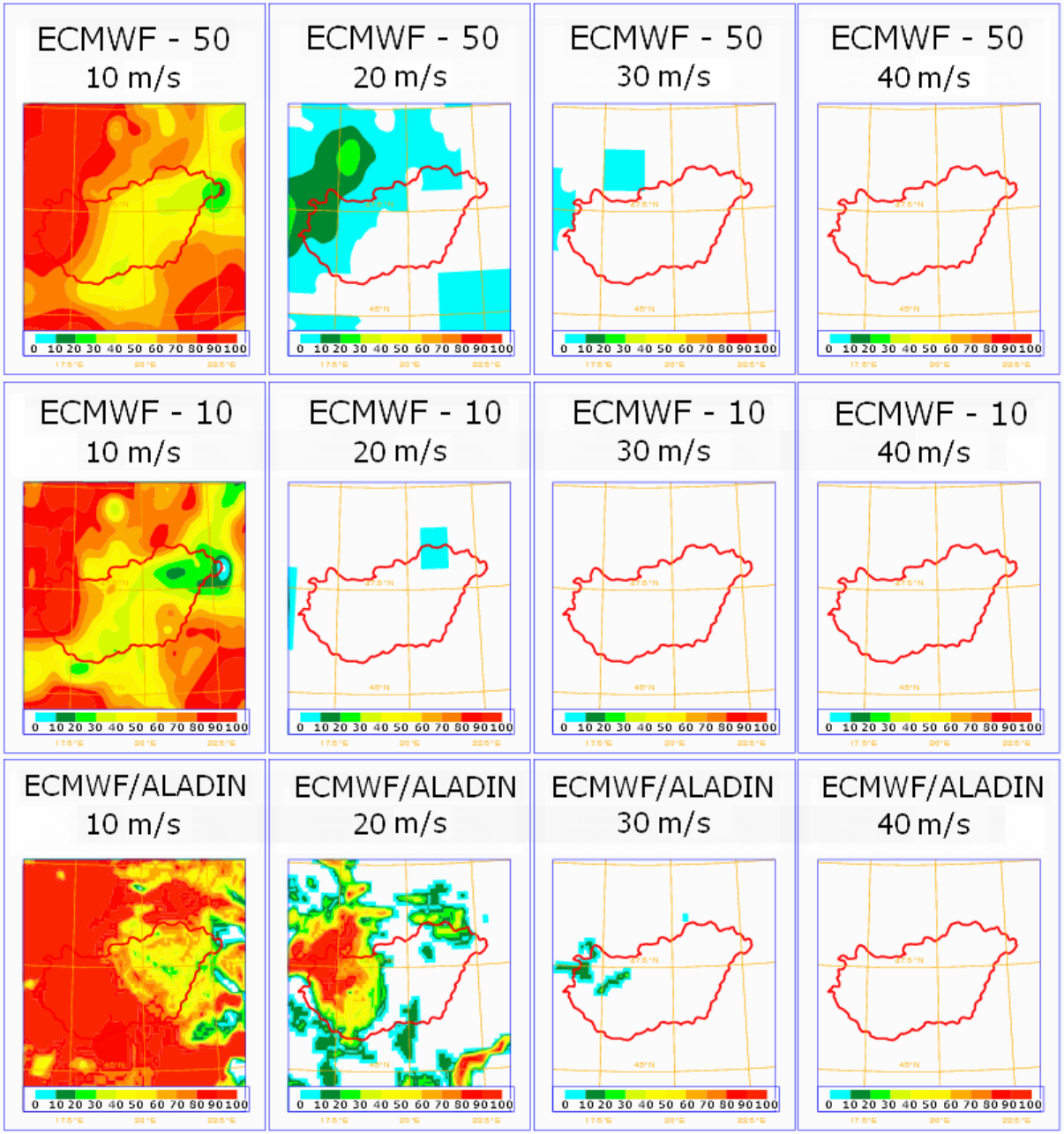
ECMWF/ALADIN
30 mm



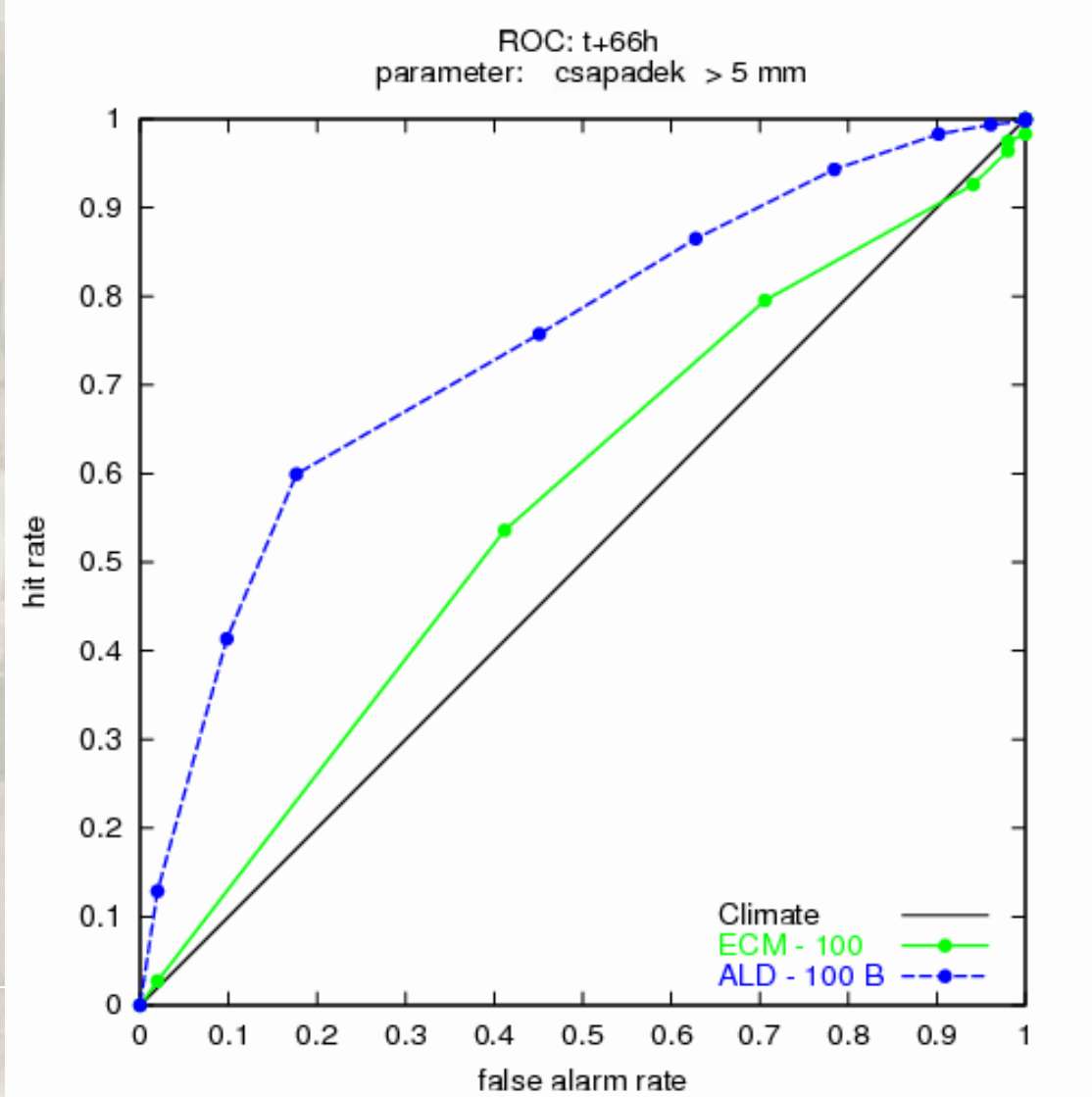
ECMWF/ALADIN
40 mm



LAMEPS activities in ALADIN: overview

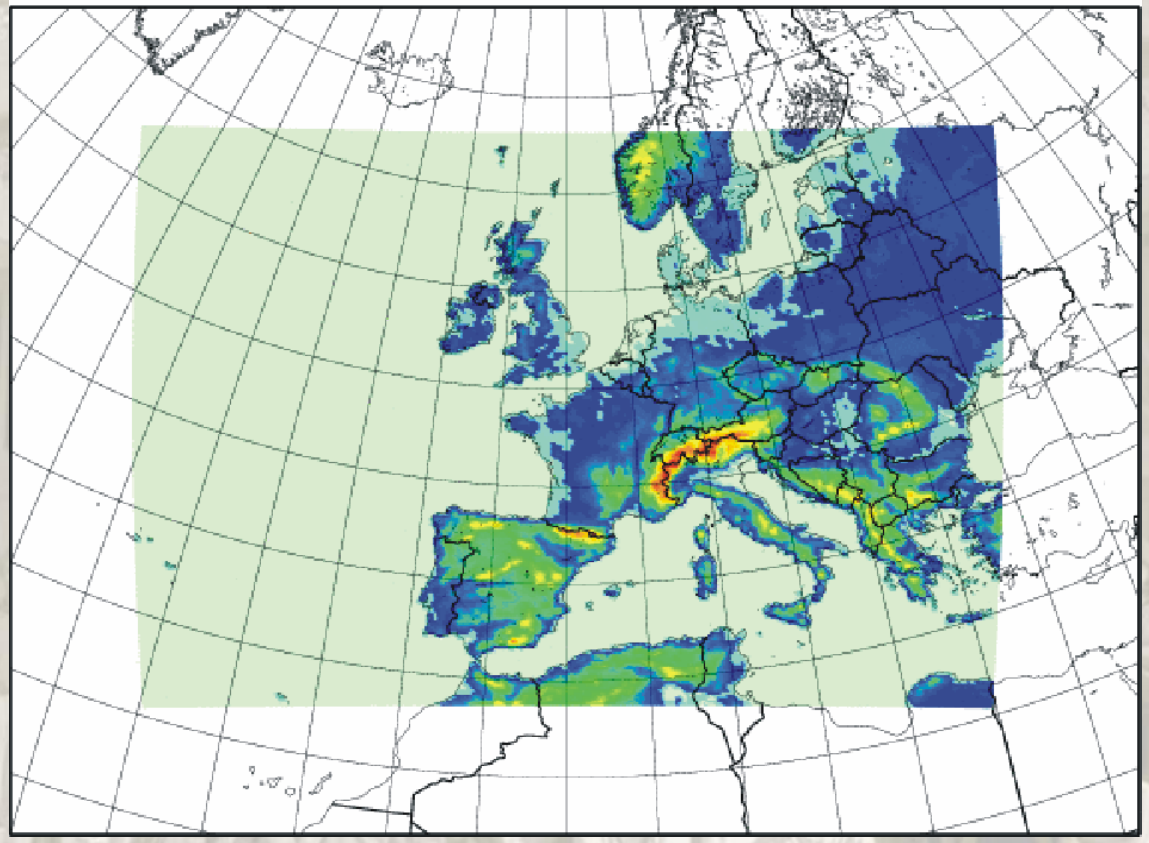


ECMWF/IFS DOWNSCALING: ROC CURVES (BASED ON THREE CASES)



BREEDING (Austria)

LAEF Domain & Topography



- **Horizontal resolution: 16 km**
- **Vertical resolution: 31 levels**
- **320x225 gridpoints**
- **time step 600s**

BREEDING

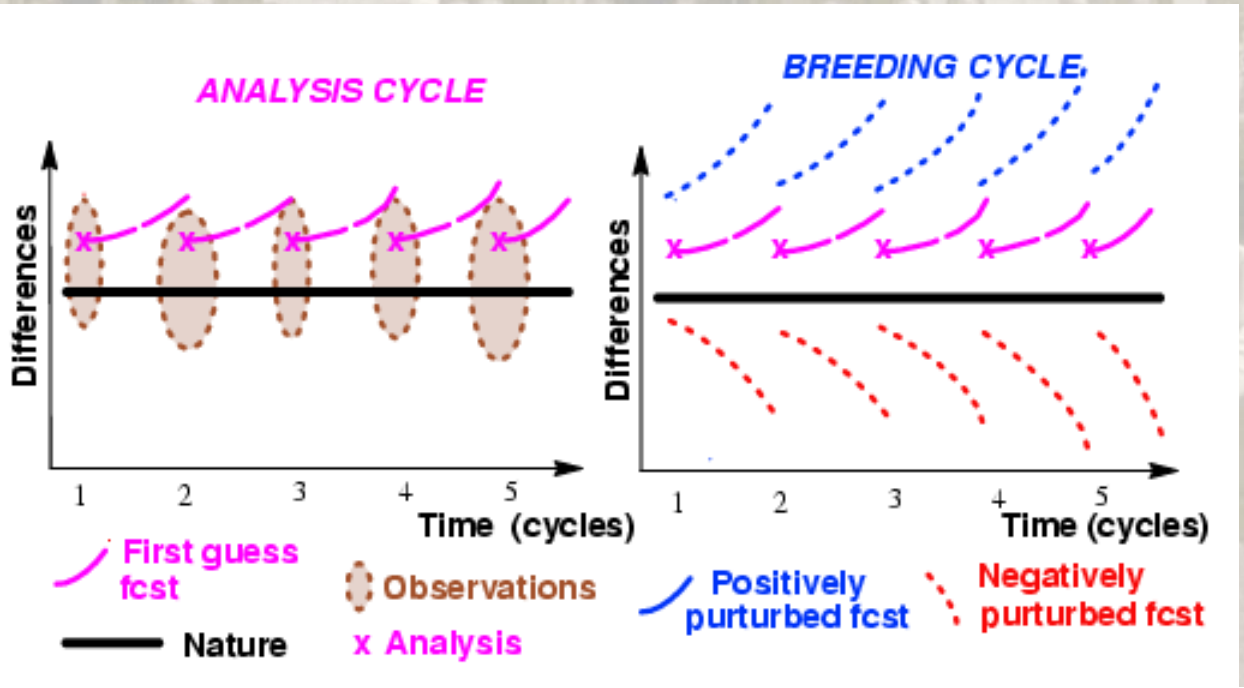
Simulate effect of observations by rescaling nonlinear perturbations

Sample subspace of most rapidly growing analysis errors:

*Extension of linear concept of Lyapunov Vectors into nonlinear environment;

*fastest growing nonlinear perturbations,

*not optimized for future growth



Toth, et.al 2004

BREEDING

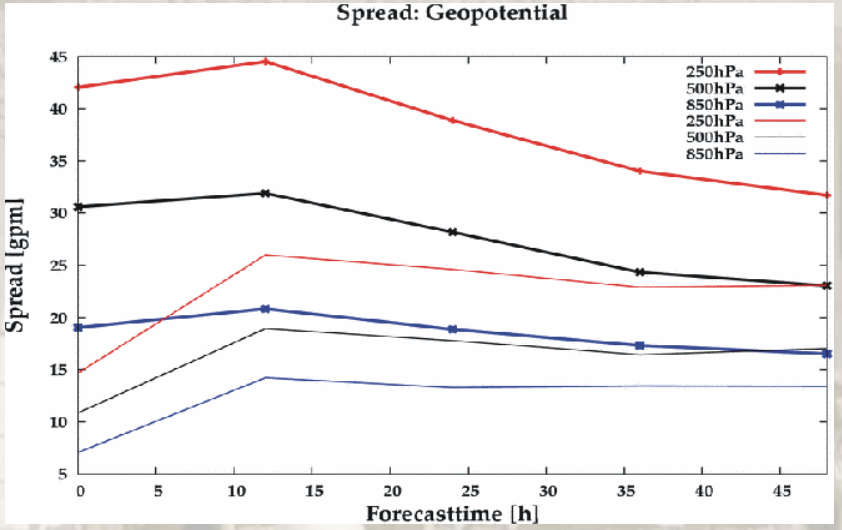
- lukewarm start
- 12 hour breeding cycle
- u, v, T, q and Ps at each gridpoint/level
- centering around the control
- constant rescaling
- Coupling with ARPEGE control or SV EPS

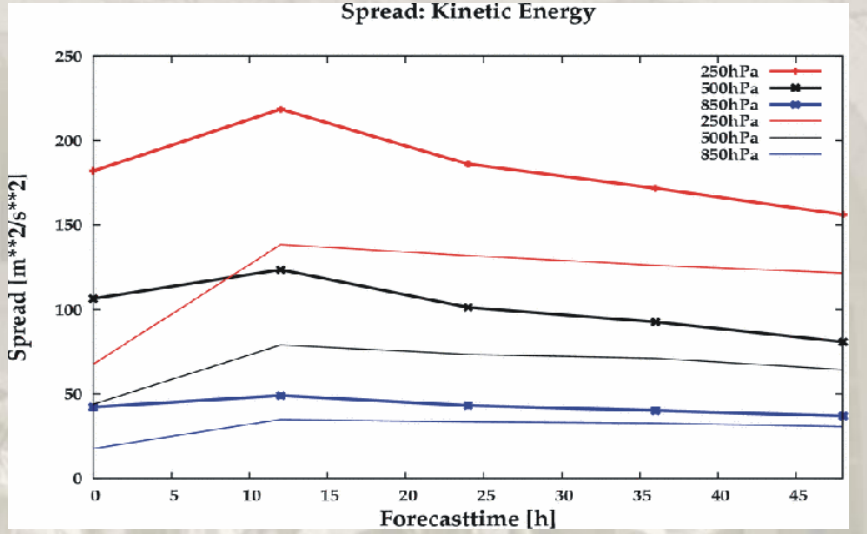
EXPERIMENTS

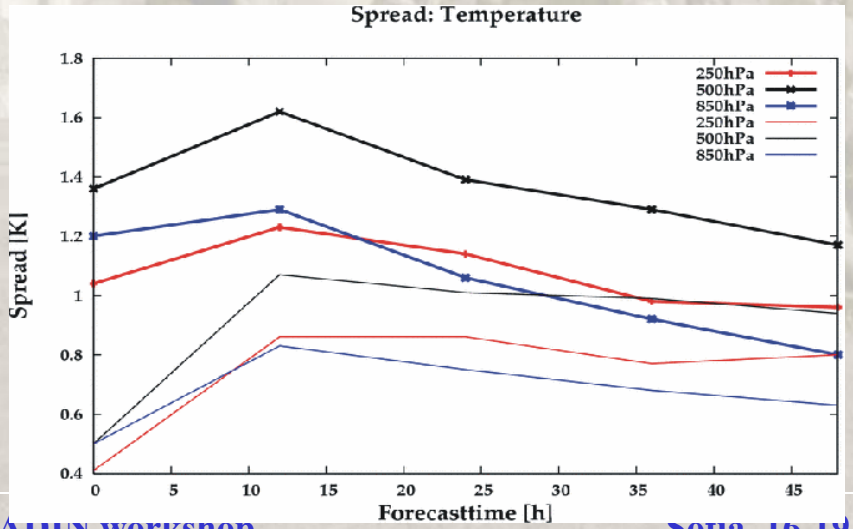
Lothar storm case: 14 Dec. 1999 to 28 Dec. 1999
11 members, integration up to 48 hours.

1. 24h vs. 12h breeding cycle
2. Coupling with control LBC vs. SV EPS
3. Downscaling vs. breeding
4. Downscaling vs. direct global SV EPS

Breeding: 24/12h cycle, scaling factor



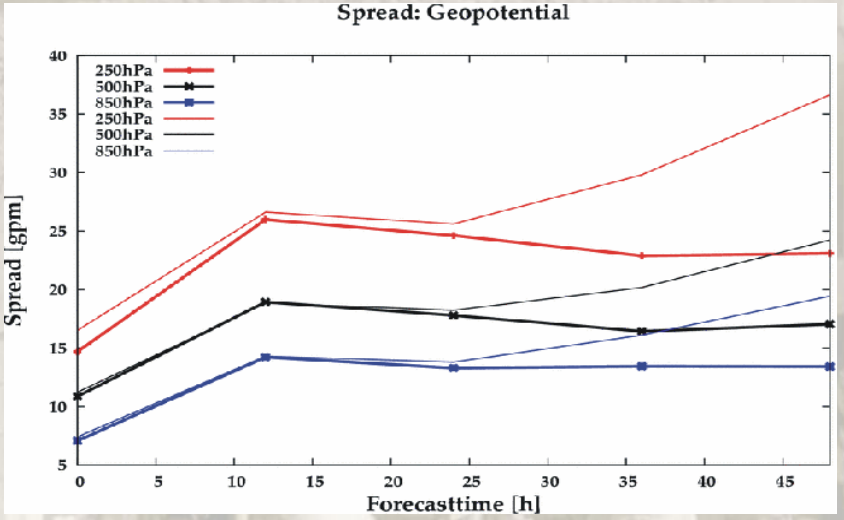


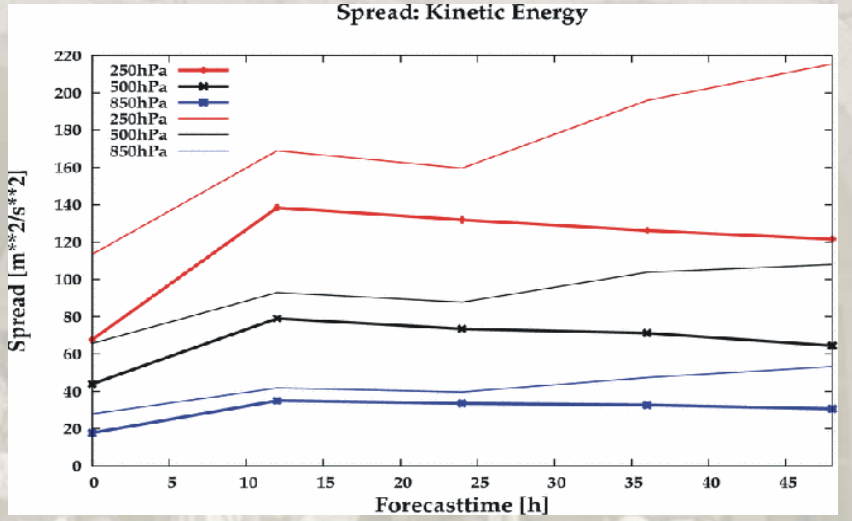


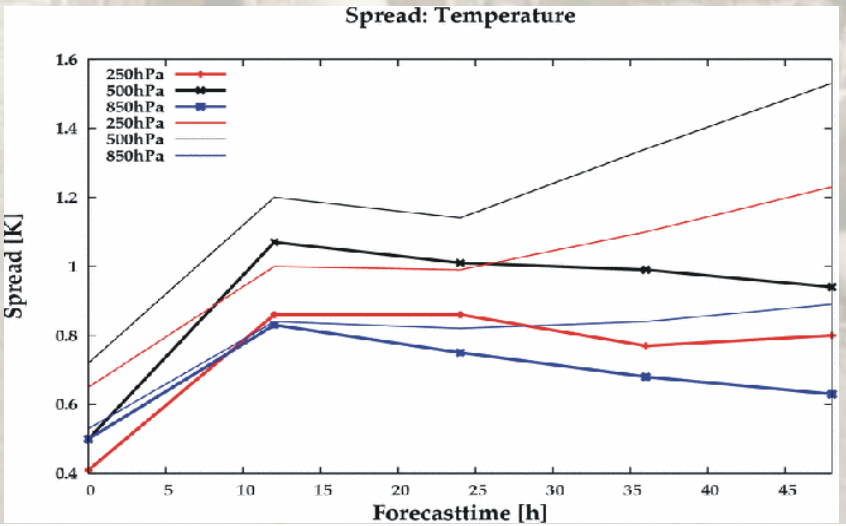
Thick line: breeding, 24h cycle, control LBC, 1.2 tunning constant

Thin line: same as above, but 12h cycle, and 0.4 tuning constant

Breeding: impact of LBC



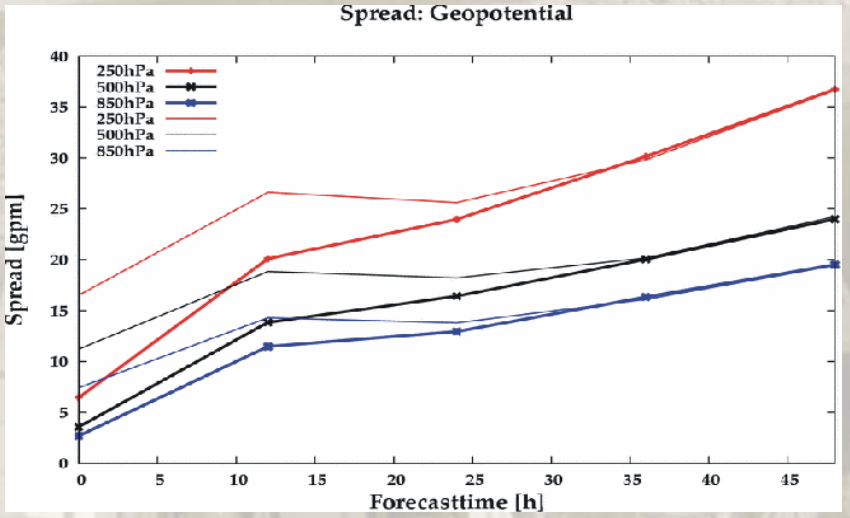


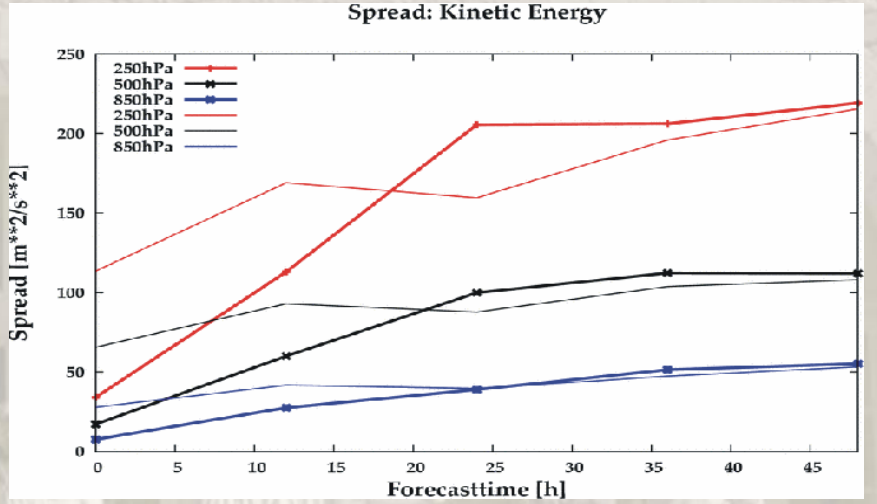


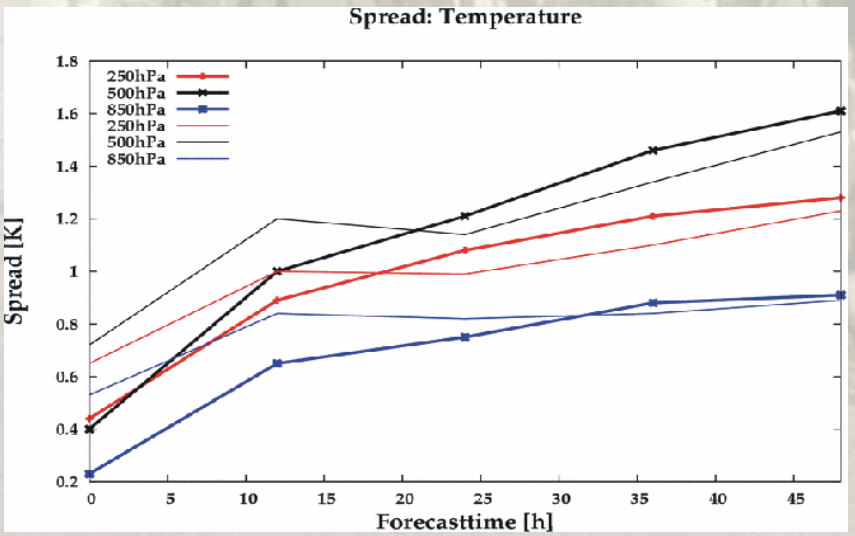
Thick line: breeding, control LBC

Thin line: breeding, ARPEGE SV EPS LBC

LAM downscaling vs. breeding



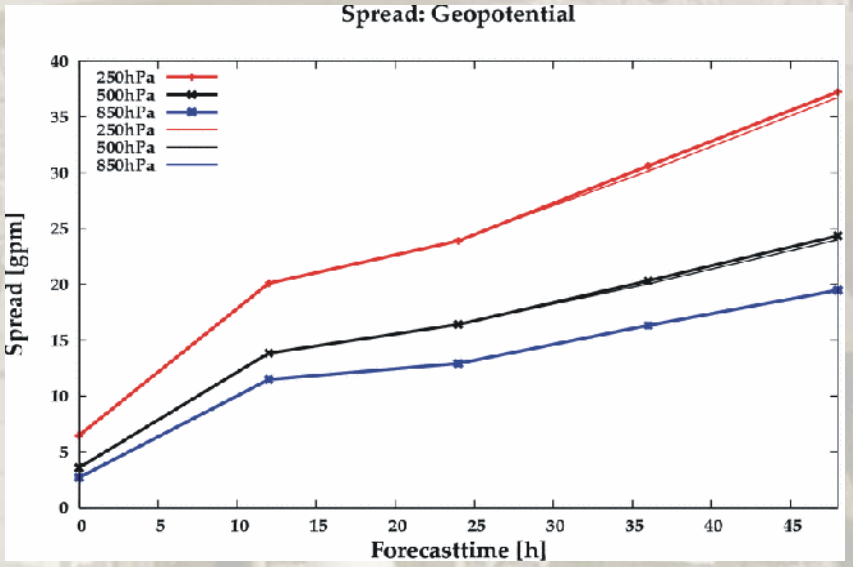


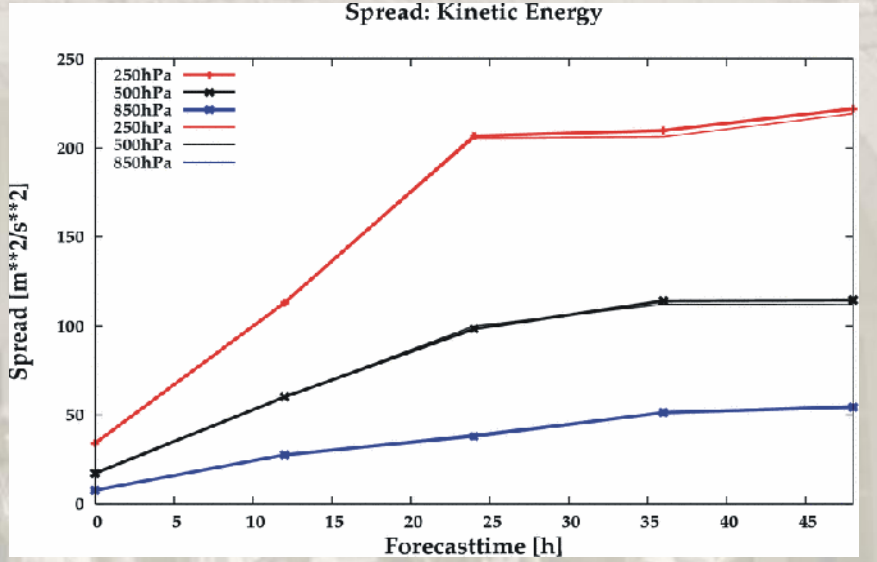


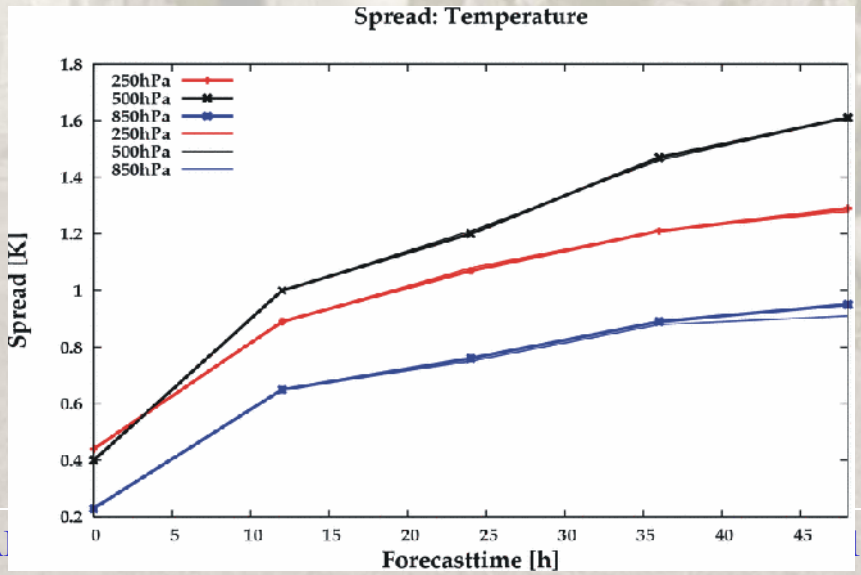
Thick line: ALADIN dynamical downscaling

Thin line: Breeding, coupled with ARPEGE SV EPS

LAM downscaling vs. global EPS

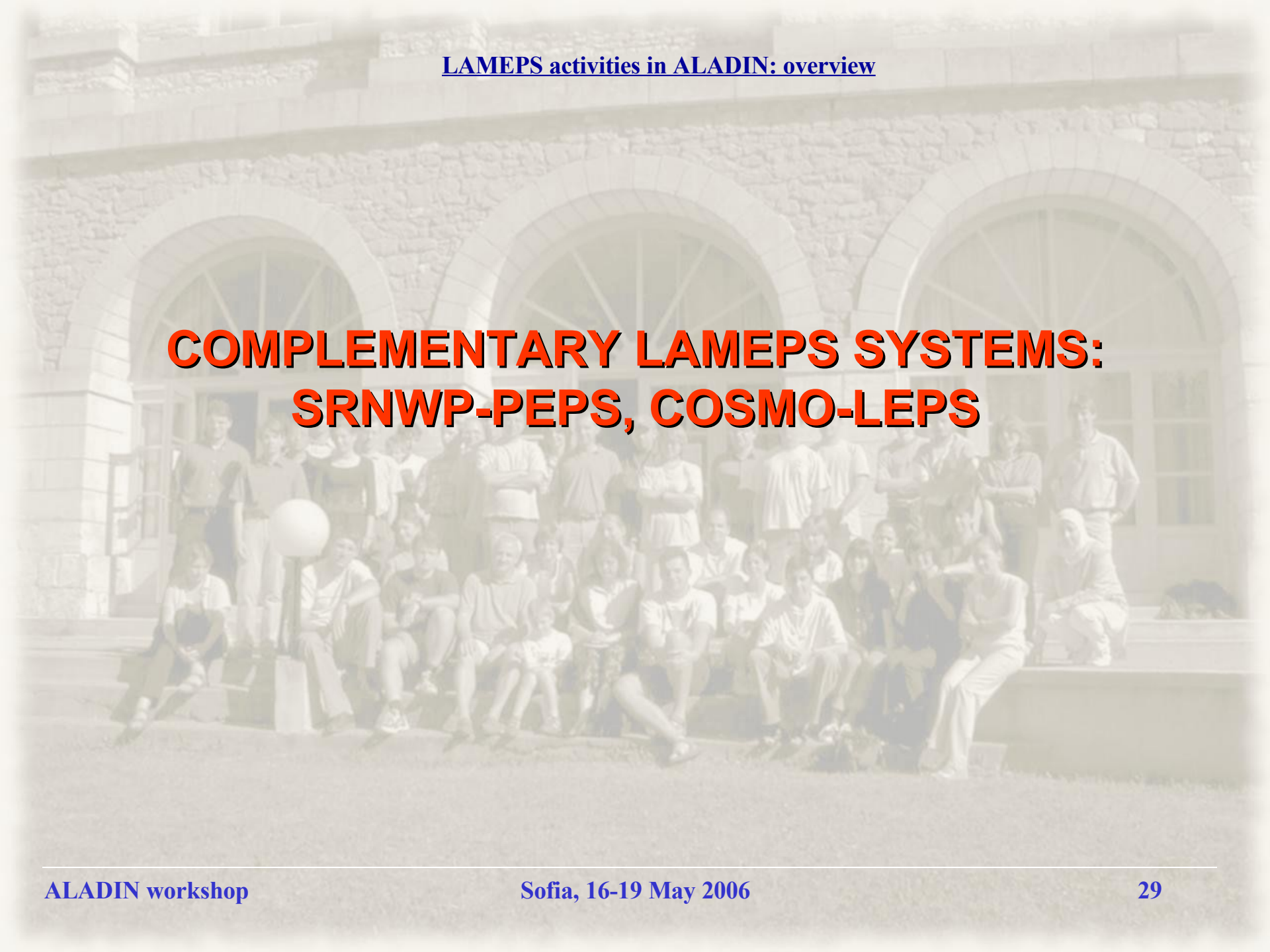






Thick line: ALADIN dynamical downscaling

Thin line: simple interpolation of ARPEGE SV EPS



COMPLEMENTARY LAMEPS SYSTEMS: SRNWP-PEPS, COSMO-LEPS

SRNWP-PEPS

- 21 members Poor Man's Ensemble
- ALADIN, HIRLAM, COSMO, UKMO consortia
- Quasi-operational short-range multi-model ensemble forecasts on a 7 km grid
- Ensemble mean and probability forecasts
- Domain size: 35°S–70°N, 30°W–30°E
- 4 runs per day (00, 06, 12, 18 UTC)
- Running at German Weather Service (DWD)

SRNWP-PEPS elorejelzes, futtatas kiindulo idopontja: 2005 06 01, 00utc
ensemble merete, hany modell fedi le a teruletet
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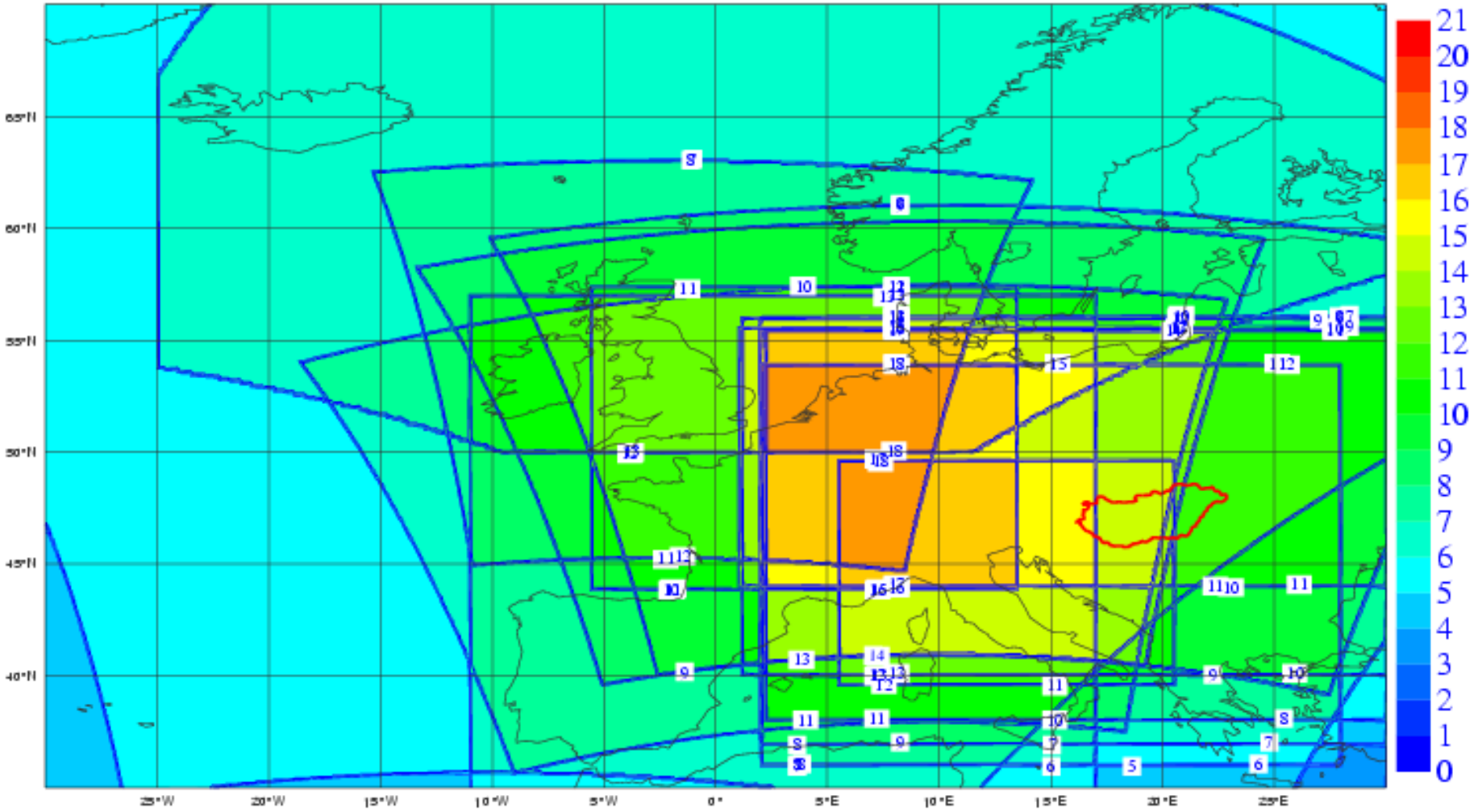

COSMO-LEPS

- Operational short-range ensemble forecasts on a 10 km grid with 16 ensemble members (until 120 hours)
- Downscaling of representative members from ECMWF EPS with the non-hydrostatic Lokal Model
- Individual ensemble members and probability forecasts
- 1 run per day (12 UTC)
- Running at ECMWF

CONCLUSIONS

Direct downscaling of global EPS

- Global EPS can be improved with targetting (domain and time)
- Generally (and frankly) speaking the improvements of LAMEPS with respect to global EPS is small
- Improvements in limited number of extreme cases

→ Local mesoscale LAM perturbations should be computed

PLANS

- Some further efforts of direct downscaling (ECMWF EPS)
- Computation of local perturbations (Austria, Hungary)
  - Breeding
  - Singular Vectors (SV)
- Explore the possibility for using ETKF and ET (Austria)
- HIRLAM: common plans (GLAMEPS)
- Stronger coordination is badly needed within Europe

Thank you for your attention!