Severe weather warnings at the Hungarian Meteorological Service: Developments and progress

István Ihász[1], Edit Hágel[1], Balázs Szintai[2]
[1]Hungarian Meteorological Service, Budapest, Hungary, [2]Eötvös Loránd University, Budapest

1 Introduction

At the Hungarian Meteorological Service (HMS) the LAMEPS project started in the second half of 2003. The aim is to develop a short range ensemble prediction system in order to understand and predict better local extreme events like heavy precipitation, wind storms, big temperature anomalies and also to have a high resolution probabilistic forecast for 2 meter temperature, 10 meter wind speed and precipitation in the 24-48 hours time range.

2 Limited area ensemble prediction by downscaling of ECMWF EPS forecasts

Limited area ensemble experiments using the ensemble forecasts of the ECMWF EPS began in the spring of 2005. This relatively late beginning of the experiments had three reasons. First of all, before 2005 the integration of the ALADIN model using ECMWF initial and lateral boundary conditions was not possible. Secondly, at the HMS the computational potential was limited before 2005, when a new supercomputer was installed. Finally, the Fortran based multivariate clustering algorithm for ECMWF EPS members was ready in the spring of 2005 (*Szintai and Ihász*, 2006).

At the European Centre for Medium-Range Weather Forecasts (ECMWF) the Ensemble Prediction System (EPS) is integrated twice a day, at 00 and 12 UTC. The horizontal resolution of the model is 80 km and it has 40 vertical levels and 50 ensemble member is derived (*Buizza*, 2001).

The ECMWF/ALADIN system is a limited-area ensemble prediction system, which has been developed at the Hungarian Meteorological Service. The goal of this project was to downscale the ensemble forecasts of ECMWF with a limited-area model called ALADIN. The main scheme of this downscaling system is the following: to reduce computational time, cluster analysis is performed on the 50 members of the ECMWF EPS, and 10 clusters are formed. From each cluster a representative member is chosen. These 10 representative members provide initial and lateral boundary conditions for the 10 ALADIN runs. According to this structure the downscaling system has two main parts: the clustering method and the ALADIN runs. In the following description of these two parts is presented.

2.1 The clustering method

The main goal of clustering is to form groups from the ensemble members in which the members are as similar to each other as possible. We used a hierarchical method to cluster the ECMWF ensemble members. According to previous studies ten clusters are used (*Montani et al.*, 2003 and *Marsigli et al.*, 2005). This cluster number was determined by taking into consideration the loss of information and the computational time. The meteorological parameters used for clustering are the geopotential, relative humidity and the two wind components at three pressure levels (500, 700 and 850 hPa), which means twelve clustering parameters. These fields were compared at two clustering times (+60 and +84h for the younger EPS), which enables the investigation of the transition of the synoptic systems. The clustering method was tested on two clustering domains. The bigger one is the same as the integration domain of the ALADIN model (34ºN–55.5ºN, 2ºE–39ºE), the smaller one is used operationally for the clustering of ECMWF EPS forecasts at HMS (*Ihász*, 2003) (40ºN–55ºN, 10ºE–30ºE). The two clustering domains are represented in *Figure 1*.

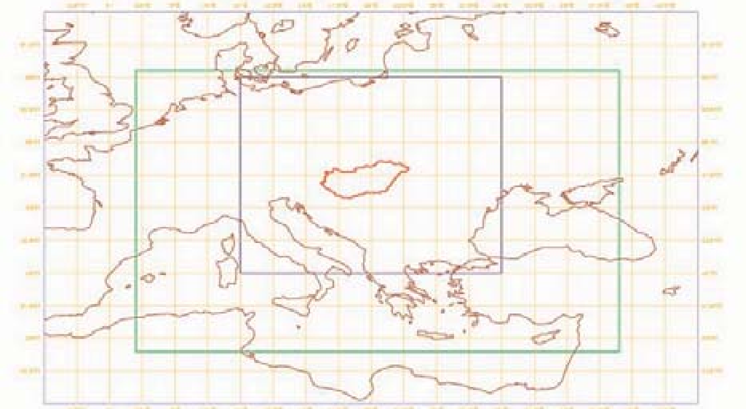


Fig. 1 The two clustering domains for the ECMWF/ALADIN downscaling system.

The ECMWF/ALADIN ensemble system was tested on four configurations. These configurations differ from each other only in the clustering method, the ALADIN runs had the same settings. The configurations were the following:

1 Clustering on the bigger domain, using one set of ECMWF EPS (50 members)

2 Clustering on the smaller domain, using one set of ECMWF EPS (50 members)

3 Clustering on the bigger domain, using two sets of ECMWF EPS (100 members)

4 Clustering on the smaller domain, using two sets of ECMWF EPS (100 members)

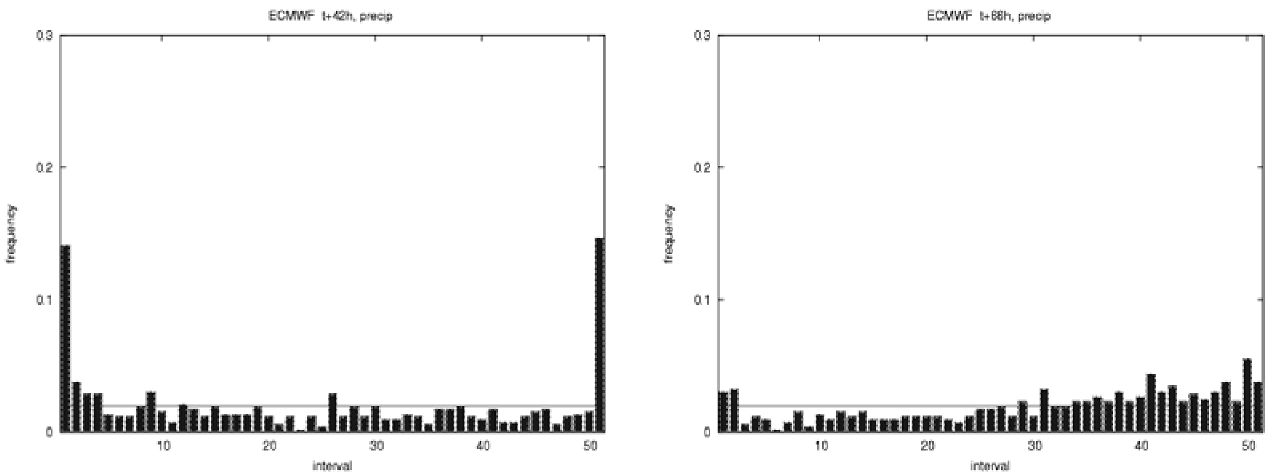
When using only one set of ECMWF EPS we used the 12 UTC EPS runs. When using two sets of EPS, we joined the 00 UTC and the 12 UTC EPS runs of the same day. In this case the initial conditions (IC) of the ALADIN runs were either the IC of the 12 UTC EPS, or the +12h forecast of the 00 UTC EPS.

ALADIN is a limited area spectral model, which has been used operationally for short-range weather forecasting at the HMS (*Horányi et al*., 1996). This model was originally designed to perform a high resolution dynamical adaptation of the ARPEGE global model. Since 2005 it is possible to integrate the ALADIN model with ECMWF IFS initial and lateral bondary conditions. To realize this the IFS GRIB files first have to be transformed into ARPEGE FA files. This transformation can be done both for deterministic and ensemble forecasts. After this transformation step the model integration can be performed in the regular way. The ALADIN model uses a bi-Fourier horizontal spectral representation. The vertical coordinate to be used is the pressure based hybrid coordinate, which is topography following at the bottom of the model and pressure type at the top of it. ALADIN model uses a semi-implicit semi-Lagrangian time integration scheme which enables the increase of the time-step.

During our experiences the model was integrated at 12 km horizontal resolution with 37 levels in the vertical; the time-step used for the integrations was about 500 s. The integration domain of the model was the bigger clustering domain. The forecast range was 84 hours..

2.2 *Objective verification*

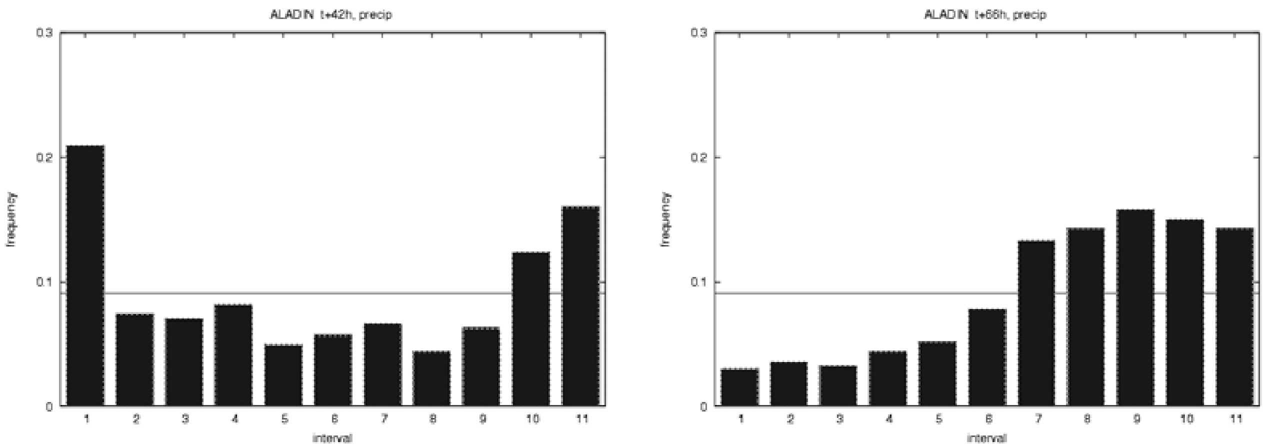
Because the verification of a longer period was not possible due to the above mentioned reason the objective verification was carried out using the forecasts of the case studies. Two different verification techniques, namely Talagrand diagrams and ROC diagrams were used for several meteorological parameters. Precipitation observations were used for verification. Data of the high-density precipitation-observing network of the HMS was used, which means more than 500 stations covered the whole area of Hungary (*Ghelly*, 2002). Observed precipitation was cumulated from 06 to 06 UTC. The 24-hour accumulated precipitation observations were averaged on 40 km boxes on Gaussian grid. In the case of precipitation the Talagrand diagrams of the ECMWF EPS (50 members) and the ECMWF/ALADIN (*Figure 2 and Figure 3*) were more similar to each other than in the case of other parameters. The diagrams shows lack of spread at the first day (+42h), and underestimation at the second day (+66h).



ECMWF 50 member EPS + 42 h forecast

ECMWF 50 member EPS + 66 h forecast

Fig. 2 Talagrand diagram for 50 member ECMWF EPS for precipitation at +42 h and 66 h.



ECMWF/ALADIN +42 h ECMWF/ALADIN +66 h

Fig. 3 Talagrand diagram for ECMWF/ALADIN (100 members, bigger domain clustering configuration) for +42h and +66h forecasts (24h accumulated precipitation)

ROC diagrams were calculated for precipitation using the observations mentioned above for the 42 hours and 66 hours forecasts. Five thresholds were used: 5, 10, 15, 20 and 30 mm. Comparing the ROC diagrams of the ECMWF EPS and the ECMWF/ALADIN it can be seen that for lower thresholds (5 and 10 mm) the hit rate of the ECMWF/ALADIN was a bit lower, but the false alarm rate of the ECMWF EPS was significantly higher (the ROC curve is not so convex). This means that the ECMWF EPS was more likely to overestimate the small amount of precipitation. Considering the 66 hours range on 70% of the grid points was more than 10 mm of precipitation forecasted (which means nearly 400 points), consequently the overestimation could be stated on the grounds of a relative wide sample. *Figure 4* demonstrates this statement by showing the ROC diagrams of the two systems for the 5mm/24h threshold.

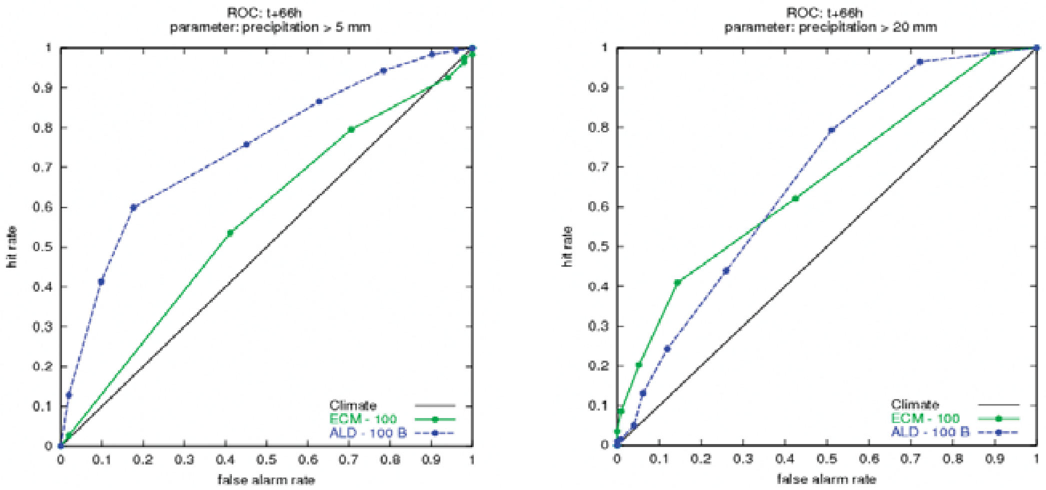


Fig. 4 ROC diagrams for 5mm/24h threshold (left) and 20mm/24h threshold (right) for +66h forecasts calculated from the three case studies. Green solid line is relative to ECMWF EPS (100 members), dashed blue line is relative to ECMWF/ALADIN (100 members bigger domain).

3 Limited area ensemble prediction by downscaling of ARPEGE EPS forecasts

LAMEPS activities started with the direct downscaling of global ensemble forecasts. Motivated by some earlier results in the field of short-range limited area ensemble forecasting (*Frogner and Iversen*, 2001, 2002; *Hersbach et al.*, 2000) it was decided to investigate the sensitivity of the global singular vector computation in terms of target domain and target time with the main goal to find an optimal configuration for a Central European application. For the experiments the ARPEGE/ALADIN (ARPEGE: **A**ction **R**echerche **P**etite **E**chelle **G**rande **E**chelle, ALADIN: **A**ire **L**imitée **A**daptation dynamique **D**eveloppement **I**nter**N**ational) model system was used considering the ARPEGE based global ensemble system, PEACE (**P**revision d'**E**nsemble **A** **C**ourte **E**chéance) as a starting point. On the one hand direct downscaling of the PEACE system was performed and on the other hand an ARPEGE based ensemble system was built with a slight modification of PEACE. In the latter case the only difference with respect to the PEACE settings was in the choice of target domain and target time used for the global SV computation. Downscaling of the global ensemble forecasts was realized with the ALADIN model. First, case studies were investigated for significantly different meteorological situations in order to see whether the change of the target domain and target time for the global singular vector computations can have a significant effect on the quality of the forecasts valid for the Central European area. Target domains were chosen with different size and location as follows (Figure 5):

- Domain 1: covering the Atlantic Ocean and Western Europe (as used in a former PEACE version, when experiments were started at HMS),
- Domain 2: covering Europe and some of the Atlantic Ocean,
- Domain 3: covering nearly whole Europe,
- Domain 4: covering a slightly larger area than Hungary.

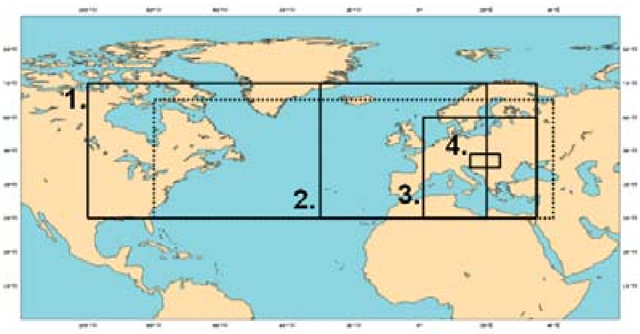


Fig. 5 The location of the four different target domains used for the experiments and the target domain used in the present PEACE system (dotted line).

As far as target time is concerned, 12 hours (as used in the PEACE system) and 24 hours were chosen. Due to the fact that the theory of SV computations is a linear one, the evolution of the singular vectors is linear. This assumption maximizes the theoretical length of the target time in about 48 hours. However the primary aim is to provide short-range forecasts, therefore a target time considerably less than 48 hours should be chosen for ensuring the desired impact of the perturbations during the forecast range. This argumentation justifies the choice having 12 hours and 24 hours as target times for the experiments.

As a general conclusion of the case studies (*Hágel and Szépszó*, 2004) one can say that the smaller the target domain the bigger the spread (not globally, just over the area where the SVs were optimized!) but with the use of very small target domains (e.g. domain 4) a significant part of the initial perturbations would propagate out from the area of interest and the spread would decrease with time which is something we would like to avoid. Therefore among the examined settings target domain 2 proved to be the optimal choice so this target domain was chosen as the subject of further examinations. Target domain 1 (as used in the PEACE system at that time) was considered as reference. Then the following four configurations were examined in detail for a 10 days summer period from 2004:

- SV target domain 1, target time 12 hours (as used in a former PEACE version, when experiments were started at HMS)
- SV target domain 1, target time 24 hours
- SV target domain 2, target time 12 hours
- SV target domain 2, target time 24 hours

Verification was performed using Talagrand and percentage of outliers diagrams. The best results were obtained when target domain 2 together with target time 24 hours was used for the global singular vector computation. Nevertheless, for surface parameters the two outermost intervals of the Talagrand diagram (not shown) were still dominating and the percentage of outliers remained much larger than the expected value (which is ~ 0.2 in our case) (*Hágel and Horányi*, 2006).

Changing (i.e. reducing the size of) the singular vector target domain yields clear improvements (especially on the higher atmospheric levels) over the verification area in terms of spread (see *Figure 6*), however one has to emphasize again that improvement in the spread does not necessarily results in better ensemble forecasts.

Unfortunately ROC and reliability diagrams could not be used for this period due to the poor sampling size resulting non-representative verification results.

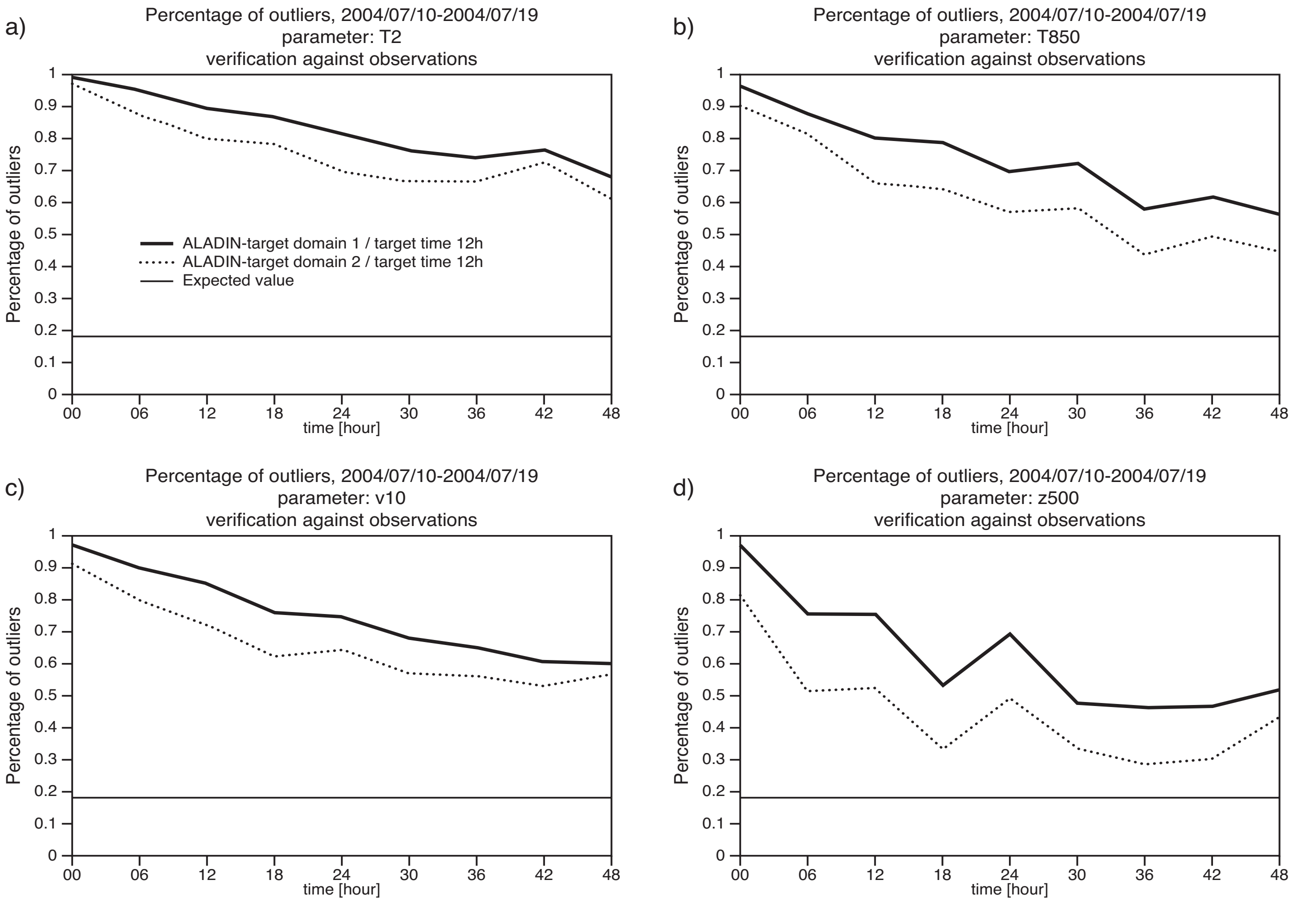


Fig. 6 Percentage of outliers diagrams for the ALADIN ensemble system for the period 2004/07/10-2004/07/19. (a.) 2 meter temperature, (b.) 850 hPa temperature (c.) 10 meter wind speed (d.) 500 hPa geopotential height. Solid line is ALADIN coupled with ARPEGE ensemble members using target domain 1 and target time 12 hours for SV computation, dashed line is ALADIN coupled with ARPEGE ensemble members using target domain 2 and target time 12 hours for SV computation. Verification was performed against SYNOP and TEMP observations. The expected value is ~ 0.2 (see the thin horizontal lines).

Based on the result of the 10 days summer period and inspired by the fact that in between important changes took place in the PEACE system (e.g. change of resolution used or SV computation and integration), it was decided to examine the following two configurations for an additional 32 days winter period (during 2005):

- target domain and target time as used in the present PEACE system (dotted rectangle on *Fig. 5* as target domain and 12 hours as target time)
- target domain 2 and target time 24 hours.

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. For all parameters the Talagrand diagrams became flatter, the distribution moved towards the ideal one. Talagrand diagrams for 2m temperature, 850 hPa temperature, 10m windspeed and 500 hPa geopotential for +60h are shown on figure 7.

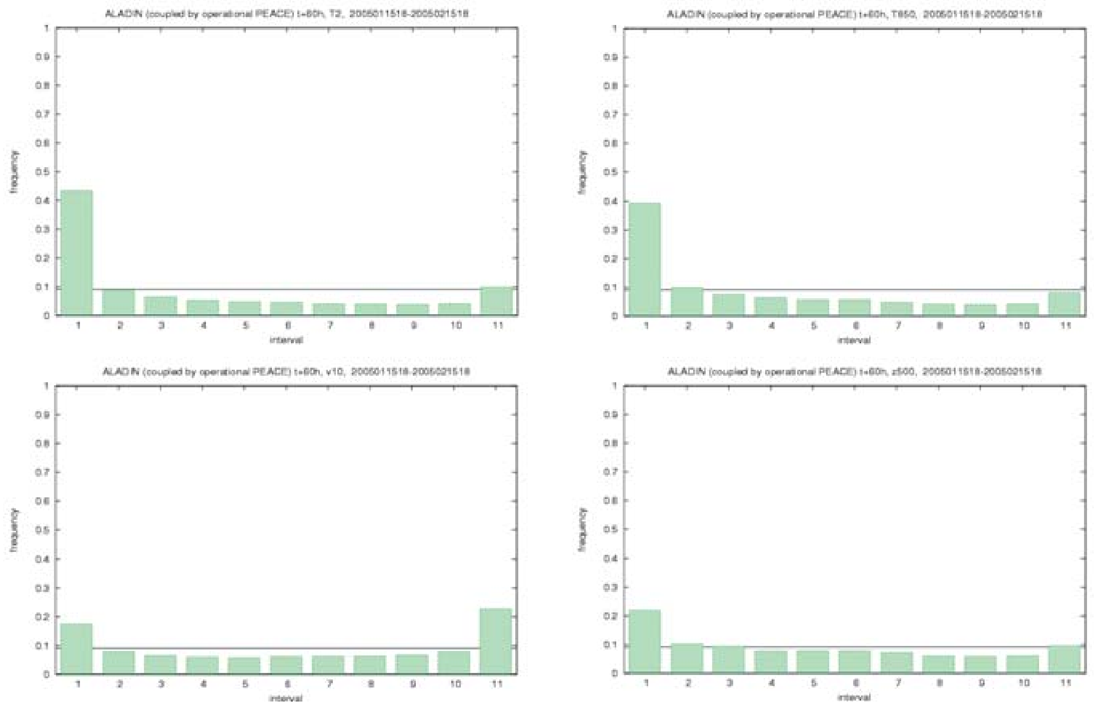


Fig. 7 Talagrand diagrams for 2m temperature, 850 hPa temperature, 10m windspeed and 500 hPa geopotential for +60h (from left on the top to right on the left).

4 Case studies

The main goal of short range ensemble forecasting is to improve forecasts of extreme weather events, consequently the system was tested on some case studies as well. Three case studies have been completed so far, which were the following:

1. 18 May 2005: the so-called Slovenian squall line, which caused heavy precipitation and strong wind gusts.
2. 11 July 2005: Cyclone over Hungary, which caused heavy precipitation.
3. 22 August 2005: Mediterranean cyclone, which caused heavy precipitation.

For the subjective verification of these extreme events stamp diagrams and probability maps were used both for the original ECMWF EPS and for the downscaling system. In the following the results for the event occurred on 18 May 2005 is presented.

On 18 May 2005 a Slovenian squall line passed through Hungary and caused heavy precipitation and strong wind gusts. Because of the good convective conditions super cells formed both in the western and eastern part of the country. The 24 hour accumulated precipitation exceeded 30 mm over several areas (Figure 8). A two day forecast was carried out for this event, so the forecast was started from 12 UTC 16th of May. In the following the results of the first clustering configuration is presented (50 members, bigger domain). Figure 9.a. shows the stamp diagram for the ECMWF EPS. On the diagram one can see the 24-hour accumulated precipitation forecast of the 10 representative members, the deterministic forecast (bottom right picture) and the observations. Figure 9.b shows the stamp diagram for the downscaling systems.

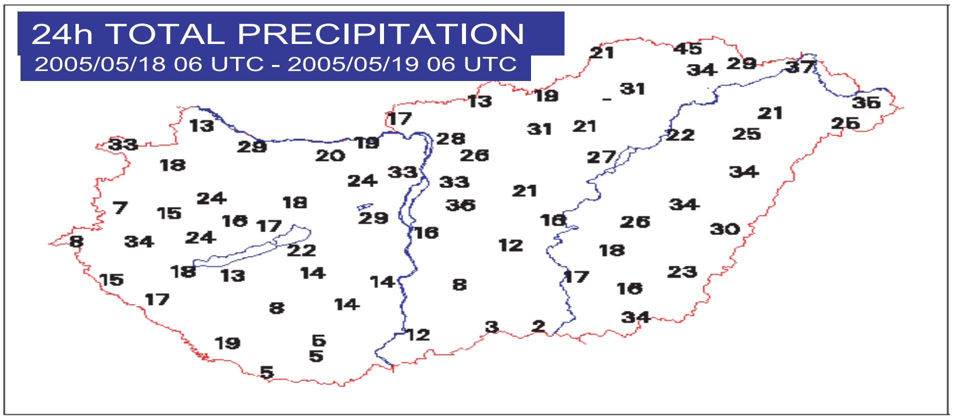
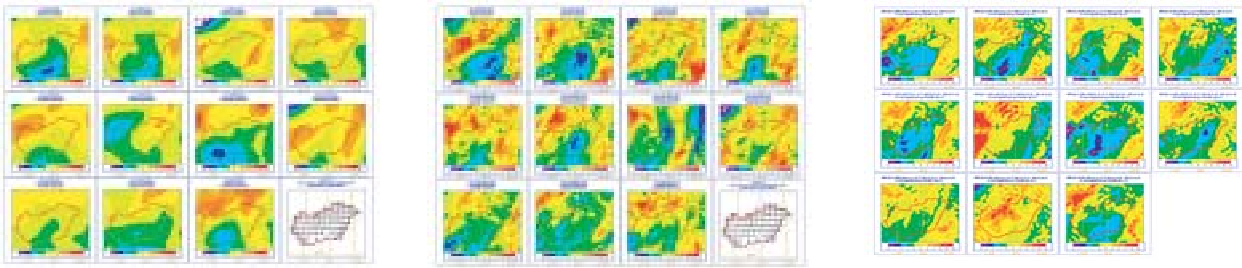
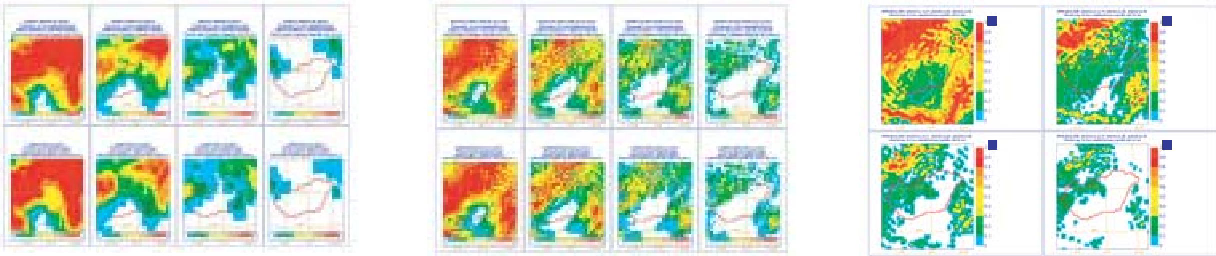


Fig. 8 24 h observed precipitation between 06 UTC 18 May 2005 and 06 UTC 19 May 2005



ECMWF 10 representative members   ECMWF/ALADIN   ARPEGE/ALADIN



ECMWF 10 representative members   ECMWF/ALADIN   ARPEGE/ALADIN

Fig. 9 Stamp diagram for ECMWF 10 representative members, downscaled ECMWF/ALADIN and ARPEGE/ALADIN model, orange and red colours indicate high amounts (30, 40 mm/24h) /top/. Probability maps for ECMWF 10 representative members, downscaled ECMWF/ALADIN and ARPEGE/ALADIN 24h precipitation exceeding 10, 20, 30 and 40 mm /bottom/.

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