 HUNGARY

Application and verification of ECMWF products 2007

Hungarian Meteorological Service

1. Summary of major highlights

The objective verification of ECMWF forecasts have been continued on all the time ranges from medium range forecast to seasonal forecast. Comprehensive subjective evaluation of short range forecast of ALADIN and ECMWF models was done as in the previous years. Some new operational products were developed in last two years, like 100 members EPS plume, extended range (15 day) plume and meteogram.

2. Use and application of products

2.1 Post-processing of model output

2.1.1 Statistical adaptation

In 2005 a statistical post-processing was introduced at the Hungarian Meteorological Service. As a first step the MOS technique based on multiple linear regression was chosen for implementation. This procedure aimed to correct the numerical forecasts (ALADIN/HU, ECMWF) of the 2 m temperature, relative humidity and the 10 m wind (u, v component). More details are available in *'Verification of ECMWF products, 2006'*.

2.1.2 Physical adaptation

Forward and backward trajectories /FLEXTRA/ and dispersion model /MEDIA and FLEXPART/ are operationally launched for predefined central European points /nuclear power plants/. MM5 is running operationally driven by ECMWF deterministic model. Case studies have been made for dynamical downscaling of ECMWF EPS products with the ALADIN/HU mesoscale limited area model (Szintai and Ihász., *2006*).

2.1.3 Derived fields

Clustering for Central European area has been operationally made since 2003. Cluster mean and representative members of the clusters are derived, a wide [V1]selection of the meteorological fields is available to the forecasters for both the short and medium time range. Several derived parameters from the deterministic and ensemble models are operationally available too. More details are available in *'Application and verification of ECMWF products, 2004'*. Altogether more than 100 EPS fields are derived.

2.2 Use of products

A wide range of the products are operationally available within the Hungarian Advanced Workstation (HAWK-2) for forecasters. Beside this tool quite a lot of special products, like EPS meteograms, EPS plumes, cluster products are available on intranet for the whole community of the meteorological service. EPS meteograms are available for medium, monthly and seasonal forecast ranges. Some new graphical products were developed in last two years, among others 100 member EPS plume, special EPS meteogram for wind direction and plume finally 15 day VarEPS plume (Fig.1)

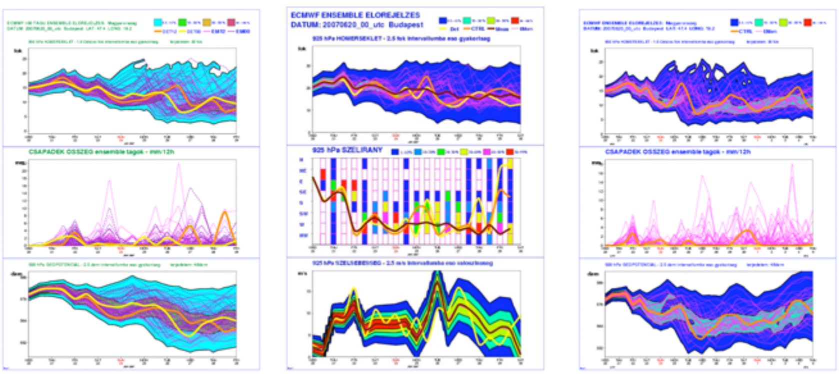


Fig. 1 100 member EPS plume, EPS meteogram for wind direction /middle graph in middle panel/ and 15 day VarEPS plume[V2]

3. Verification of Products

3.1 Objective verification

3.1.1 Direct ECMWF model output

(i) in the free atmosphere

(ii) local weather parameters for locations

The objective verification has been performed by the Objective Verification System (OVISYS) produced by the Hungarian Meteorological Service. More details are available in *'Verification of ECMWF products, 2006'*.

In the recent study the 00 and 12 hours runs of ECMWF model were verified against all the Hungarian SYNOP observations for the whole 2006 year. The input forecast values for ECMWF were taken from a 0.5°x0.5° post-processing grid. The verification was performed for the following variables:

- 2m temperature
- 2m relative humidity
- 10m wind speed
- Total cloudiness
- Minimum and maximum 2m temperature
- Daily accumulated amount of precipitation

BIAS and RMSE scores until 168 hours (only for ECMWF) are computed. The computed scores are presented on Time-TS diagrams (with the forecast range on the x-axis) (Fig 2-7).

2m temperature:

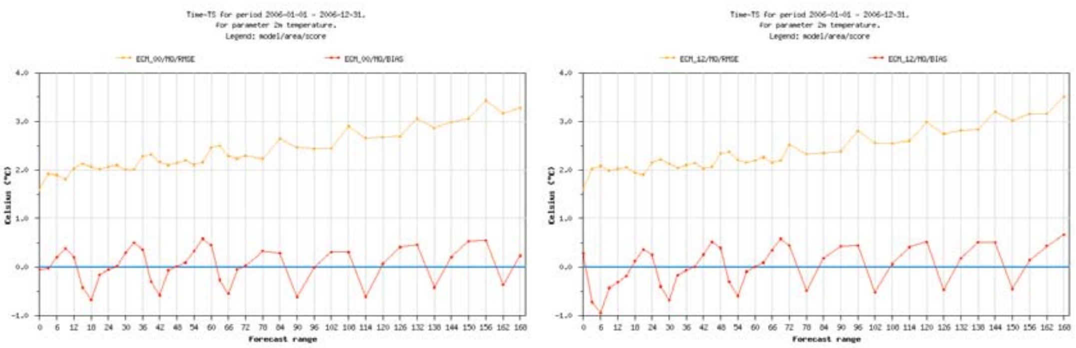


Fig. 2 RMSE and BIAS values for ECMWF 2m temperature forecasts for Hungary. The RMSE values are slightly increasing with the forecast range and the BIAS fluctuates around zero with a strong diurnal cycle.

2m relative humidity:

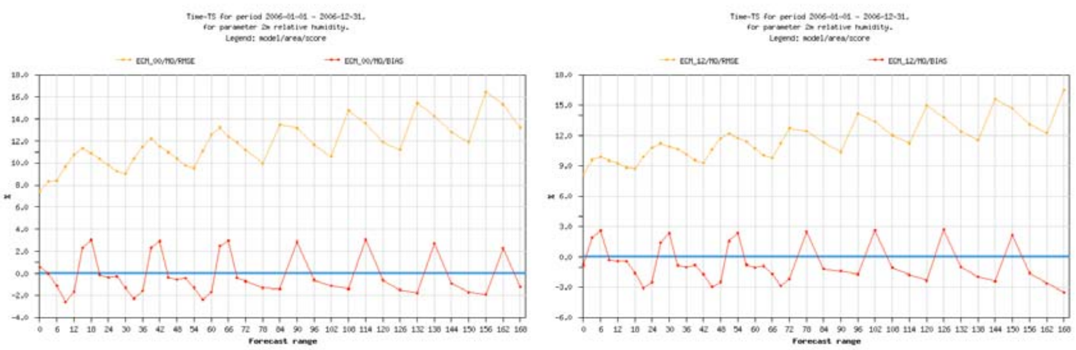


Fig. 3 RMSE and BIAS values for ECMWF 2m relative humidity forecasts for Hungary. The RMSE values are slightly increasing with the forecast range and the BIAS fluctuates between -3 and 3 % with a strong diurnal cycle.

10m wind speed:

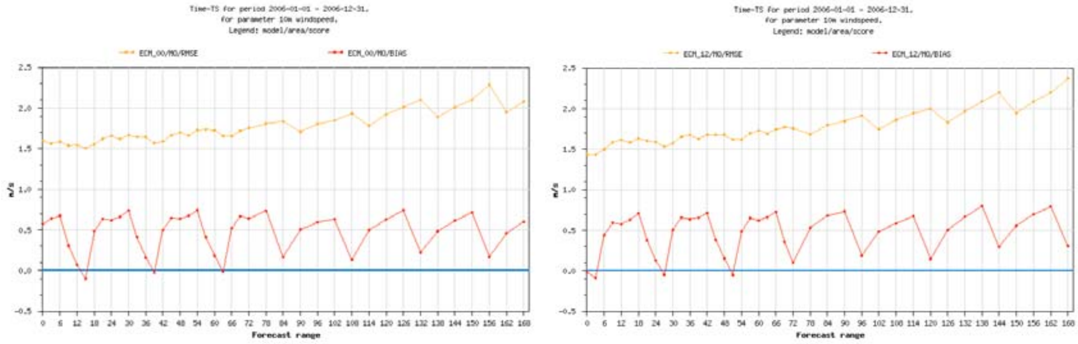


Fig. 4 RMSE and BIAS values for ECMWF 10m wind speed forecasts for Hungary. The RMSE values are rather constant in the first couple days, then there is a slight increase afterwards. The BIAS fluctuates in a diurnal cycle at a range of about 0.3 m/s (first 3 days) and of about 0.5m/s (later).

Total cloudiness:

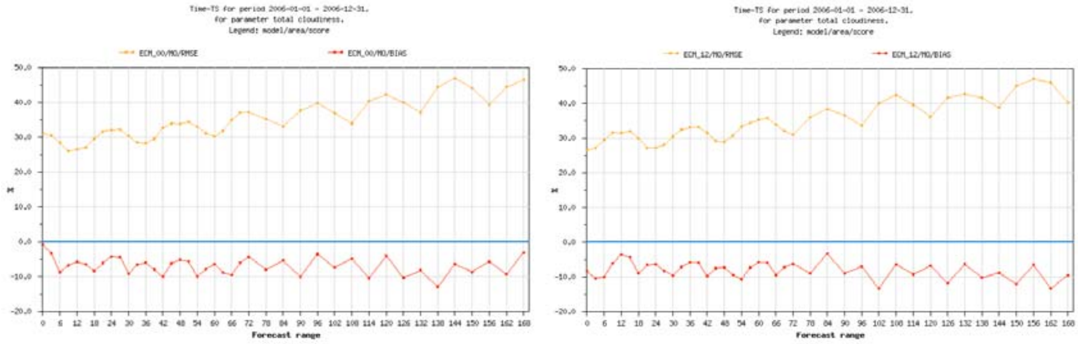


Fig. 5 RMSE and BIAS values for ECMWF total cloudiness forecasts for Hungary. There is a cloudiness underestimation at all ranges (around -5 and -10 percent). The RMSE values are strongly increasing along the forecast ranges.

2m minimum and maximum temperature:

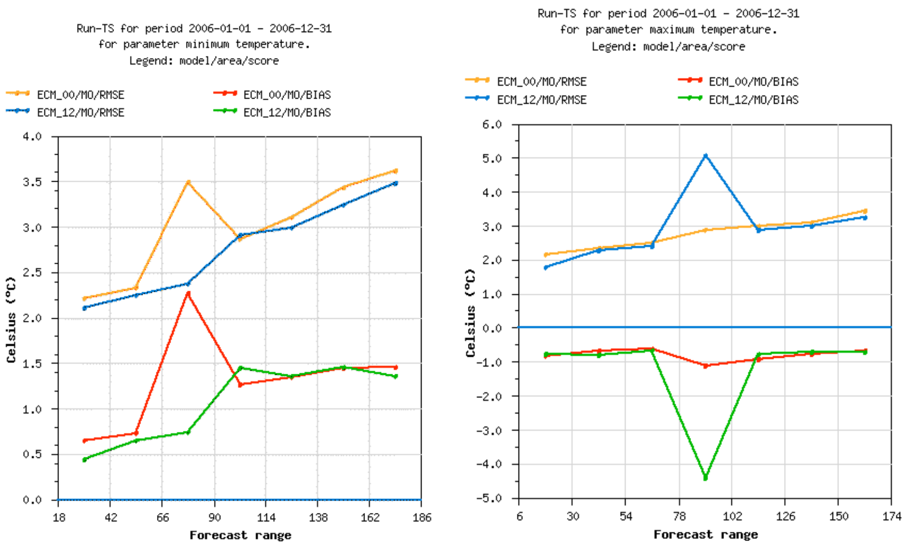
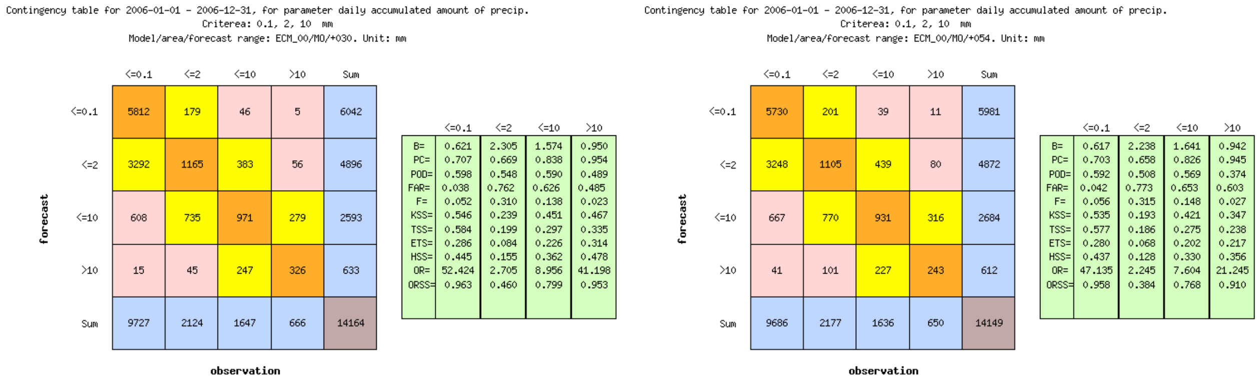


Fig. 6 Comparison of BIAS and RMSE values for daily minimum (left) and maximum (right) temperature for ECMWF 00 and 12 UTC runs. The scores show that the models overestimate the minimum temperature and underestimate the maximum temperature.

Daily accumulated amount of precipitation:



Contingency table for 2006-01-01 - 2006-12-31, for parameter daily accumulated amount of precip.
Criterea: 0.1, 2, 10 mm
Model/area/forecast range: ECM_00/MO/+030. Unit: mm

forecast \ observation	<=0.1	<=2	<=10	>10	Sum
<=0.1	5812	179	46	5	6042
<=2	3292	1165	383	56	4896
<=10	608	735	971	279	2593
>10	15	45	247	326	633
Sum	9727	2124	1647	666	14164

	<=0.1	<=2	<=10	>10
B=	0.621	2.305	1.574	0.950
PC=	0.707	0.669	0.838	0.954
POD=	0.598	0.548	0.590	0.489
FAR=	0.038	0.762	0.626	0.485
F=	0.052	0.310	0.138	0.023
KSS=	0.546	0.239	0.451	0.467
TSS=	0.584	0.199	0.297	0.335
ETS=	0.286	0.084	0.226	0.314
HSS=	0.445	0.155	0.362	0.478
OR=	52.424	2.705	8.956	41.198
ORSS=	0.963	0.460	0.799	0.953

Contingency table for 2006-01-01 - 2006-12-31, for parameter daily accumulated amount of precip.
Criterea: 0.1, 2, 10 mm
Model/area/forecast range: ECM_00/MO/+054. Unit: mm

forecast \ observation	<=0.1	<=2	<=10	>10	Sum
<=0.1	5730	201	39	11	5981
<=2	3248	1105	439	80	4872
<=10	667	770	931	316	2684
>10	41	101	227	243	612
Sum	9686	2177	1636	650	14149

	<=0.1	<=2	<=10	>10
B=	0.617	2.238	1.641	0.942
PC=	0.703	0.658	0.826	0.945
POD=	0.592	0.508	0.569	0.374
FAR=	0.042	0.773	0.653	0.603
F=	0.056	0.315	0.148	0.027
KSS=	0.535	0.193	0.421	0.347
TSS=	0.577	0.186	0.275	0.238
ETS=	0.280	0.068	0.202	0.217
HSS=	0.437	0.128	0.330	0.356
OR=	47.135	2.245	7.604	21.245
ORSS=	0.958	0.384	0.768	0.910

Fig.7 Contingency table for the 24 h accumulated precipitation for the second forecasted day (between 30 h and 54 h forecast ranges) of the 00 UTC runs. The scores show that the ECMWF model underestimates the large precipitation events and generally overestimate the small precipitation events.

3.1.2 ECMWF model output compared to other NWP models used by the HMS

Hereafter the ECMWF and ALADIN/HU models will be compared in the first 48 forecast ranges with the help of OVISYS. The forecast values from ECMWF are taken from a 0.5°x0.5°, while for the ALADIN model from a 0.1°x0.1° post-processing grid (the original mesh size of the ALADIN model is 8km on Lambert projection). The scores are computed against SYNOP observation for the Hungarian territory for the year of 2006 (Fig. 8-11).

2m temperature:

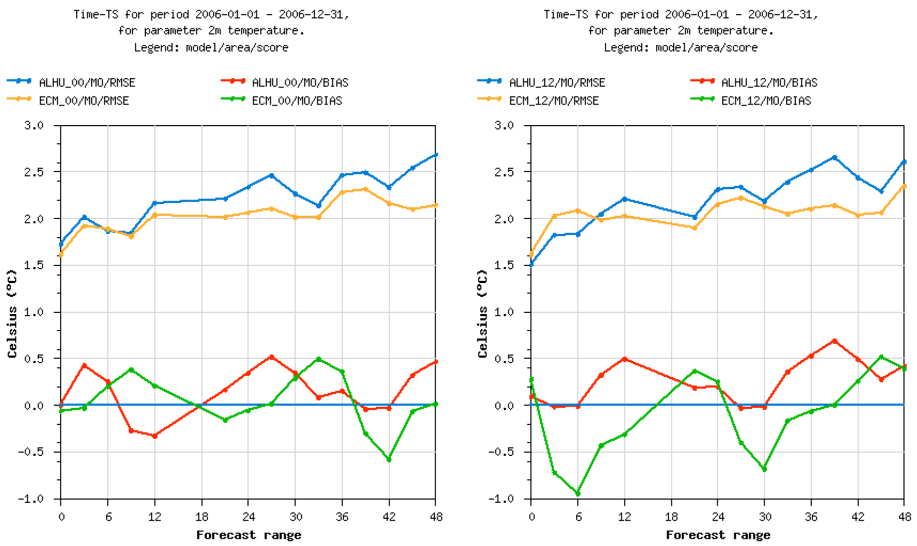


Fig.8 Comparison of BIAS and RMSE values for ECMWF and ALADIN 2m temperature forecasts over Hungary. The scores are similar with some advantage of the ECMWF forecasts from the second day onwards (in terms of RMSE). It is interesting to note that ALADIN is rather overestimating and the ECMWF model is rather underestimating the temperature (and the diurnal cycle for ECMWF is much stronger).

2m relative humidity:

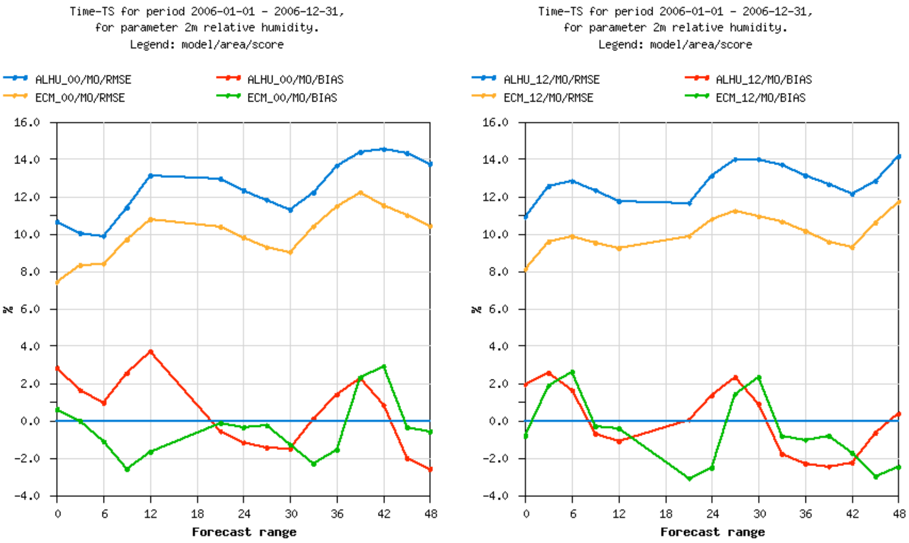


Fig.9 Comparison of BIAS and RMSE values for ECMWF and ALADIN 2m relative humidity forecasts over Hungary. The ECMWF forecast is significantly better in terms of RMSE.

10m wind speed:

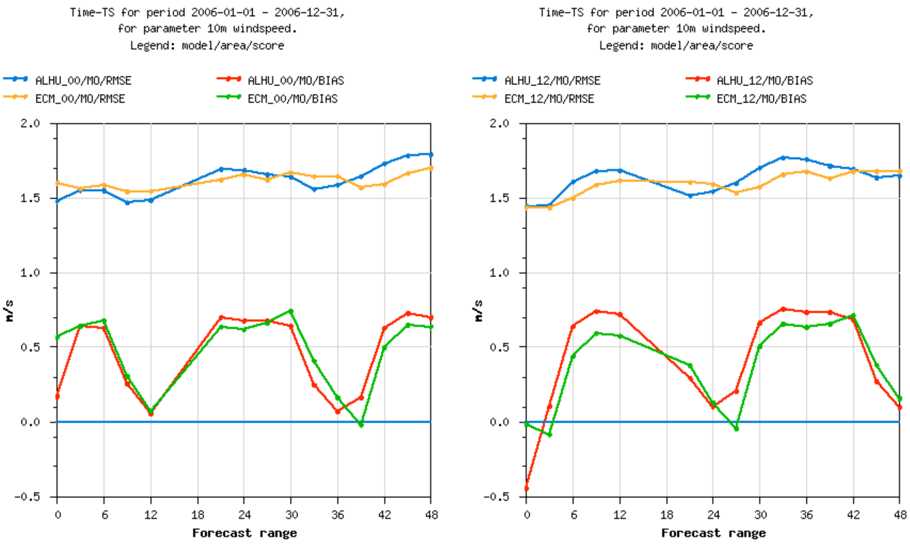


Fig.10 Comparison of BIAS and RMSE values for ECMWF and ALADIN wind speed forecasts over Hungary. There is no significant difference between the two model forecast.

Total cloudiness:

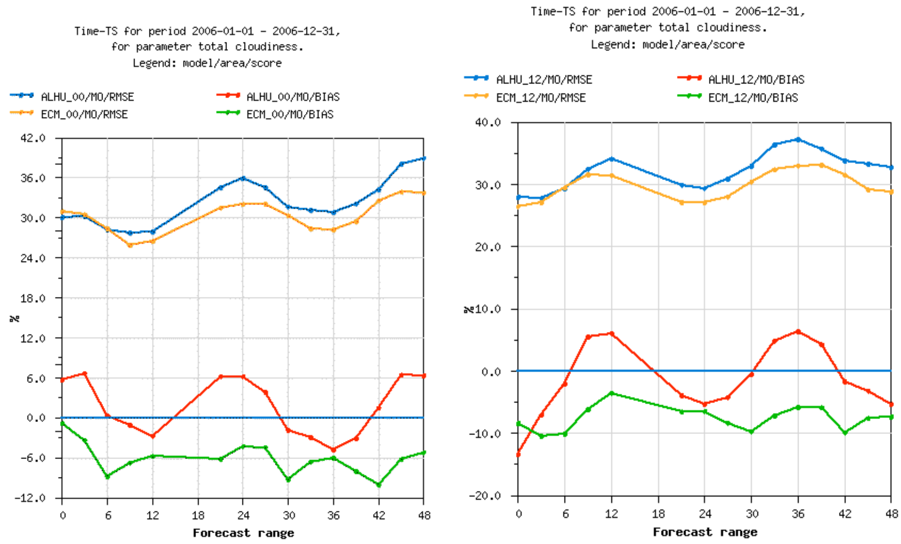


Fig.11 Comparison of BIAS and RMSE values for ECMWF and ALADIN total cloudiness forecasts over Hungary. Except the first few hours the RMSE values of the ECMWF forecasts are smaller than that of the ALADIN ones. There is a systematic underestimation in the ECMWF forecasts.

3.1.3 Post processed products

Post processed products are regularly verified in OVISYS. On Fig. 12 RMSE of the raw and post processed 2m temperature and 2m relative humidity forecasts is shown for 2006.

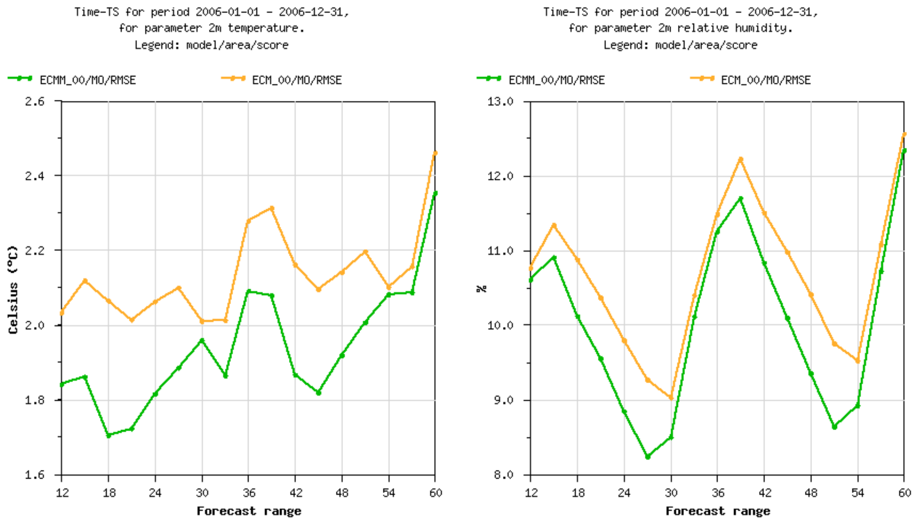


Fig. 12 RMSE of 2m temperature and 2m relative humidity

3.1.4 End products delivered to users

End products have been verified since 1999. Forecasters are regularly able to improve the forecast quality (Fig. 13).

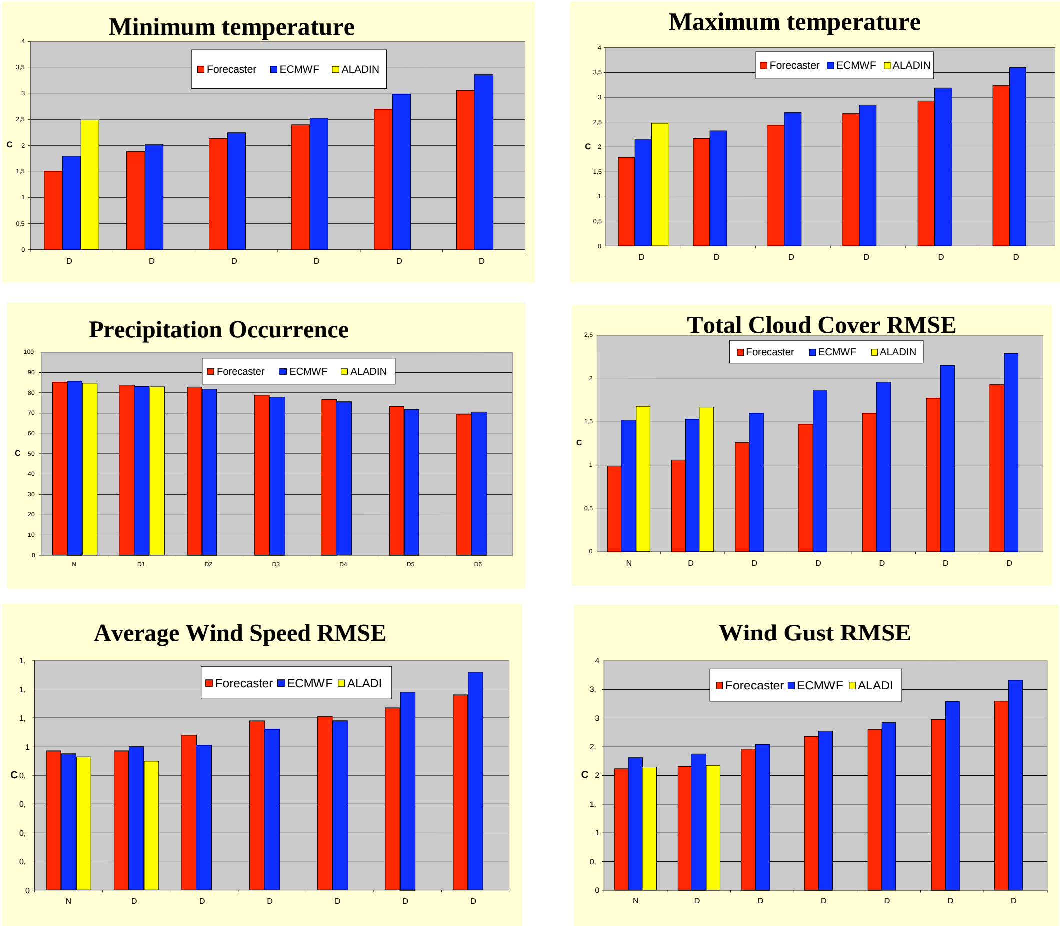


Fig. 13 RMSE of temperature, total cloud cover, average wind speed and wind gust forecasts and Percent Correct (PC) of precipitation existence forecasts for different forecast ranges (D0 stands for the first night where relevant) in case of ALADIN (AL)), ECMWF (EC) and the Operational Forecaster (Fo) for 2006

3.1.5 Seasonal forecasts

The verification of ECMWF's seasonal forecasts was done using the mean error, mean absolute error and root mean square error statistics of the ensemble mean of System 2's predictions issued for the year 2006. The monthly mean of the 2 meter, maximum and minimum temperature forecasts and the predicted monthly amount of precipitation were verified. The verification was done for six regions of Hungary and for the whole country. The reference dataset while calculating the mean absolute error skill score was the climatological mean of the 1961-1990 period.

On Fig. 14 the mean absolute error skill score of the country wide average of the above mentioned parameters is shown for the six forecasted months of the seasonal forecasts. The 12 forecasts were divided into single months, the ones with the same lead time were accumulated and the verification was performed on these datasets to see how the forecasts develop in time. The 2 meter temperature forecasts show the best results of the used parameters, the forecasts for the first, fifth and sixth months show more skill than the climate, the second and third months are slightly less precise than the climate and only the forth month shows that the climate outperforms System 2 by a bigger margin. The maximum and minimum temperatures show skills close to the climatology, while the prediction of precipitation mostly performs under the climate. In the case of all parameters can be seen that there's no clear trend in the performance of the forecasts, the higher lead times don't result in poorer performance.

Since the mean absolute error skill score is normalised by the climatological mean the absolute error of the second forecasted month and of the climate average is shown on Fig. 15. The second forecasted month is chosen because that's the first one in our operational forecast.

It can be noticed that in the case of all four forecasted parameters there was a month in which the measured monthly mean was very close to the climatological value. June in the case of the 2 meter, maximum and minimum temperature and January in the case of the amount of precipitation. Because of the definition of the mean absolute error skill score this can influence the result of the verification strongly.

On the other hand the precipitation forecast shows the highest skill for the first forecasted month even though its absolute error was the greatest of the six forecasted months. The reason of this behaviour is that in the second part of the year, except for October, the precipitation predictions for the first month could predict that the amount of precipitation will differ from the average, therefore had better performance than the climatology while the other forecasted months were mostly outperformed by the climate in this period. As a summary of the results we can say that seasonal forecasting for our area is still a difficult challenge, System 2 had some good results and failures too, and we are looking forward to the outcome of System 3's forecasts.

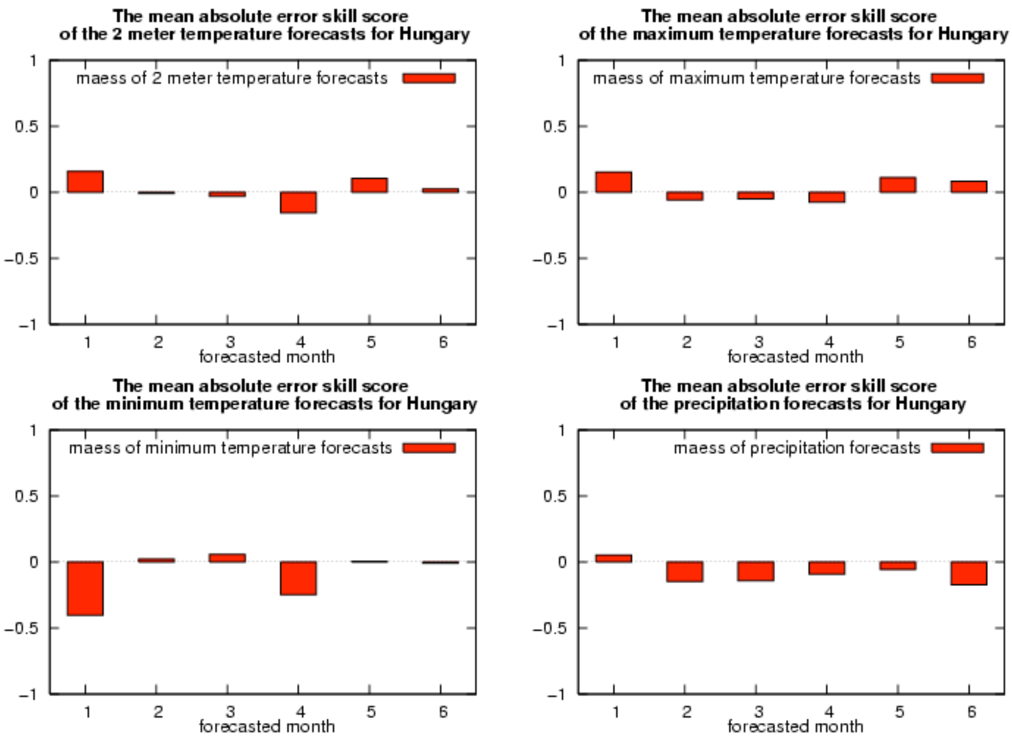


Fig. 14 Mean Absolute Error Skill Score of ensemble means of 2 meter, maximum, minimum temperature and precipitation for the 6 forecasted months in a forecast for 2006. Reference forecast was the 30-year climatological mean.

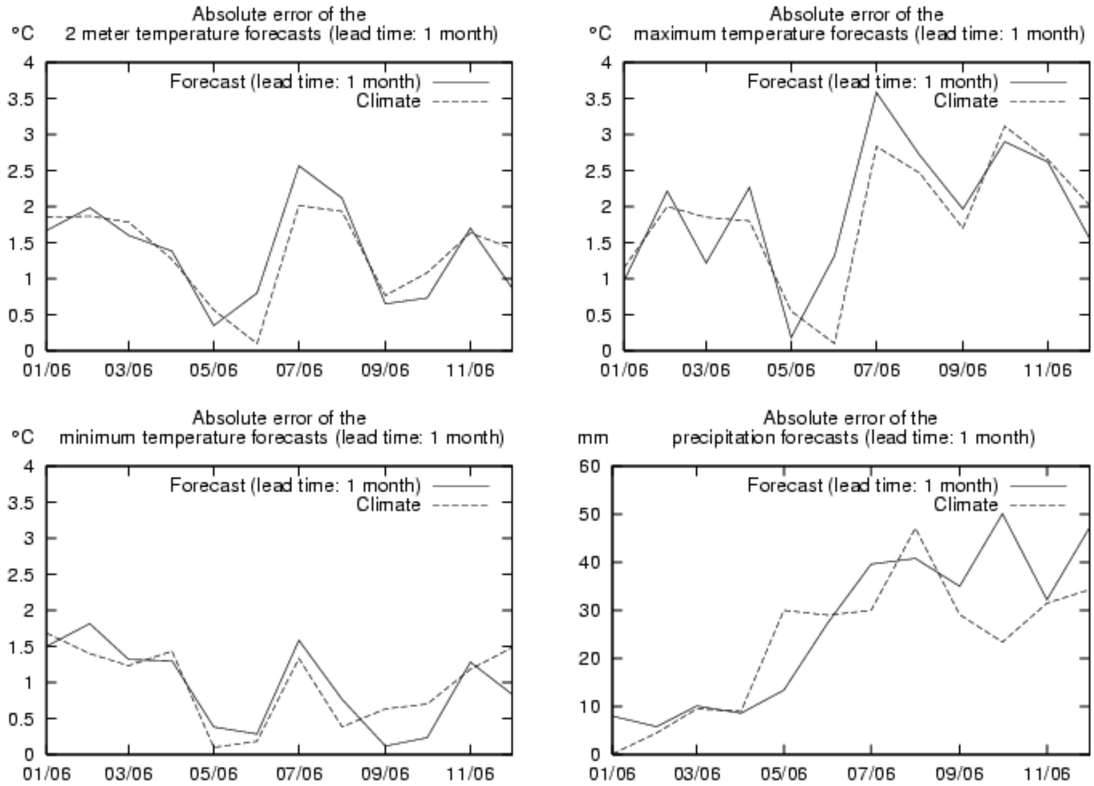


Fig. 15 The Absolute Error of the second forecasted month (1 month lead time) of seasonal forecasts for the 2 meters, maximum, minimum temperature and precipitation issued for 2006. The reference forecast is the 30-year climatological mean.

3.1.6 Monthly forecasts

Monthly forecasts have been operationally used at the HMS since the beginning of its experimental run, March 2002. Once a week ensemble means for weekly mean, minimum and maximum 2m temperature and accumulated precipitation amounts are calculated. The verification has been realized for 6 regions of Hungary and also for the entire country. The calculated statistics are the daily mean error (ME), mean absolute error (MAE) and root mean square error (RMSE) (Fig. 16). Weekly Skill Scores based on the mean absolute error are also calculated. In that case the reference dataset was the climate mean, which was expressed by the measured values averaged between 1961and 1990 (Fig. 17).

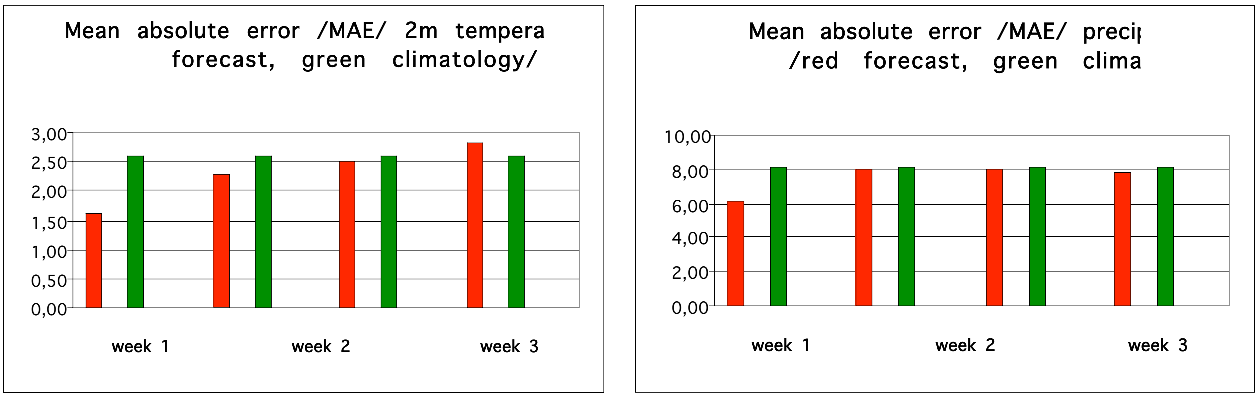


Fig. 16 Mean absolute error of weekly mean 2m temperature and precipitation /red is ECMWF forecast, green is climatology/.

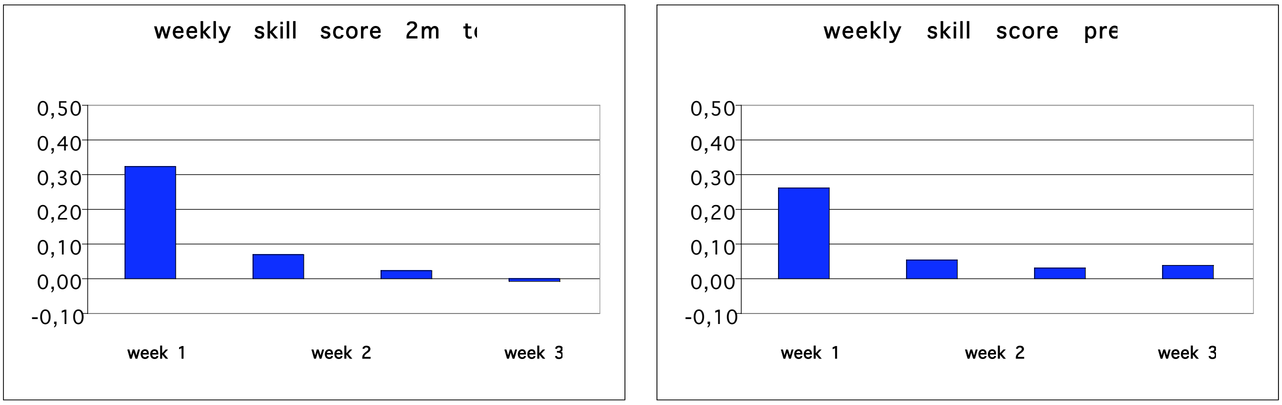


Fig. 17 Weekly Skill Scores based on the mean absolute error for 2m temperature /left/ and precipitation /right/.

Subjective verification

3.2.1 Subjective scores

The recent subjective verification started in February 2004 and it finished December 2006 due to lack of human resources. The subjective evaluation of different NWP models is compared over Hungary: the ALADIN/HU operational model different test versions of the ALADIN/HU model, and ECMWF deterministic model. The model forecasts are compared to each other and to the surface (SYNOP) and TEMP observations, radar and satellite measurements. The verified parameters are as follows: precipitation, 2m temperature, total cloudiness and 10m wind. 5-grade classification was created: being mark 5 for excellent forecast and 1 for completely wrong predictions. The forecasts based on 2 day old model integration (00-48 integration for the 00 UTC runs of ALADIN models and ECMWF model) were evaluated. The forecasts are verified subjectively in two separate time-intervals (day 1: 00-24 hours - and day 2: 24-48 hours). The evaluation is performed in a web-based system (the evaluation data is stored in a database) making possible an easier overall evaluation and an easier search for interesting cases. Fig. 18 shows the skill subjective evaluation score for precipitation, temperature, total cloud cover and wind speed in the seasons of 2006. ECMWF usually has better scores except for wind speed on day 1 and 2 in winter and total cloud cover for day 1 also in winter.

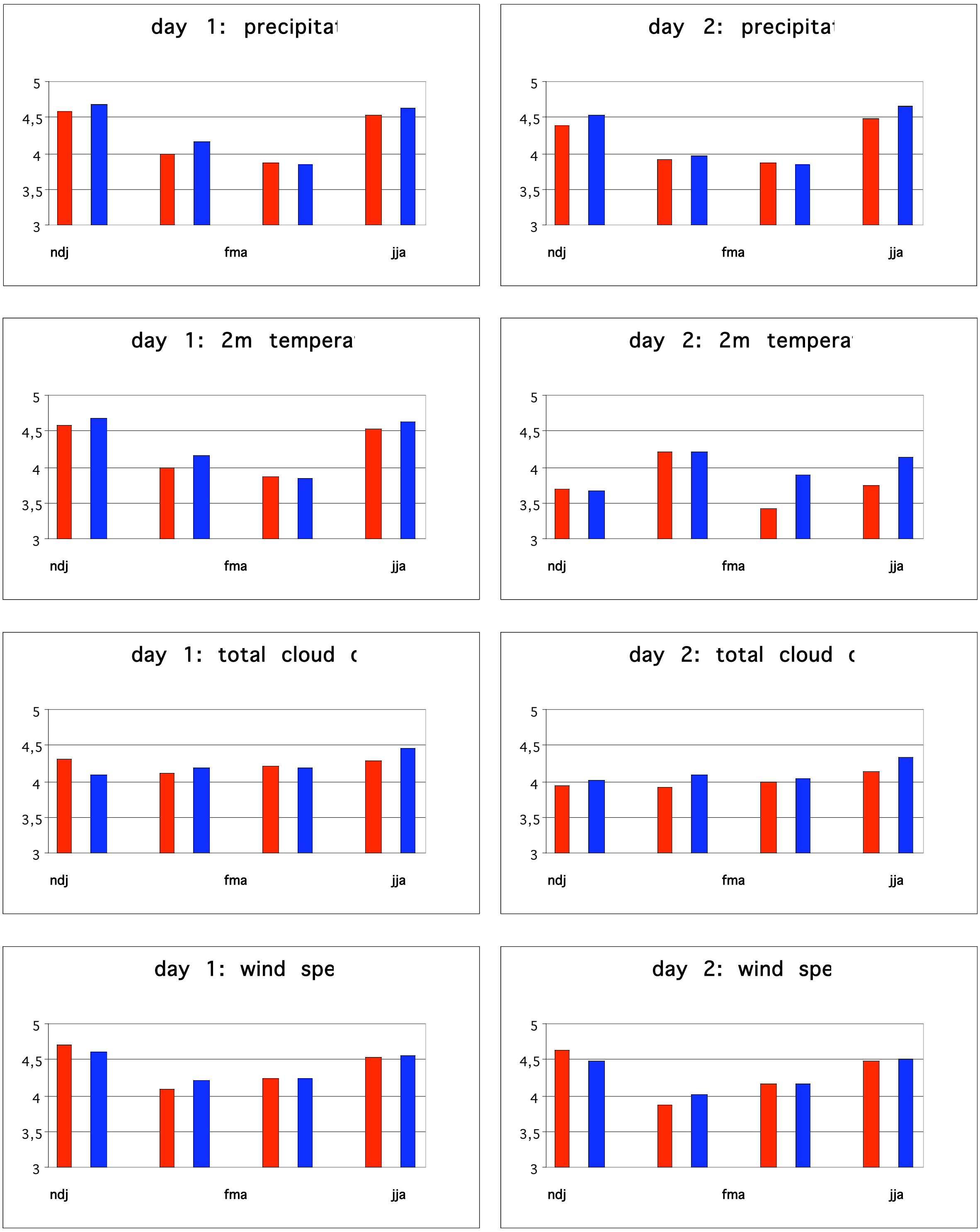


Fig. 18 Subjective verification scores for the four seasons in 2006 /ALADIN is red, ECMWF is blue/.Left panel for the first day and the right one is for the second day.

3.2.2 Case studies

Last year investigations and cases studies have been made using deterministic and EPS ECMWF forecasts (Hirsch, *2006*), (Varga, Korényi, Hirsch, *2006a*),), (Varga, Korényi, Hirsch, *2006b*). Carpathian basin is quite often strongly influenced by inversion in wintertime. There was a significant development of the forecast quality after introducing new scheme for the parametrization of low cloud in the ECMWF model (Martin Köhler, ECMWF Newsletter No. 104 Summer 2005). In spite of the new scheme inversion situations are not always captured by the model. Therefore, in these cases the model results need to be modified by the forecasters (Fig. 19 and 20). According to the figures, most of the low cloudiness was not predicted by the ECMWF model in this case.

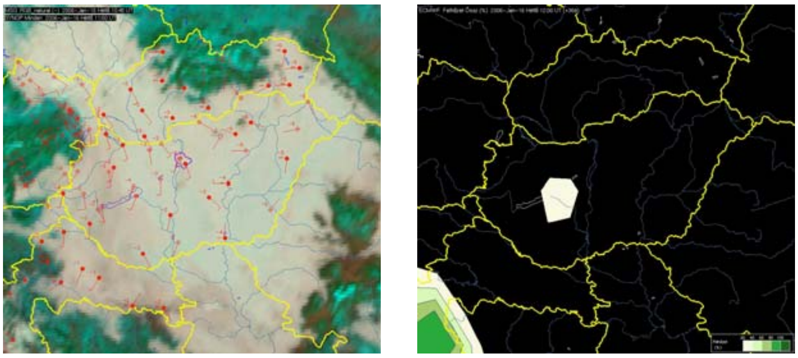


Fig. 19 MSG image 16 January 2006 11 UTC (left) and the ECMWF total cloudiness forecast 14. 01. 2006 12UTC+48h (right).

Fig. 20 shows model analysis of the cloudiness and the +12 and +36 hour cloudiness forecasts. Looking at the model analysis, it can be seen, that the model was able to capture the inversion cloudiness in the analysis but in the forecasts, cloudiness was significantly underpredicted. So, according to our investigation, it seems that even if the models are able to capture lower cloudiness or fog, the breaking of the inversion is too early in the model compared to reality.

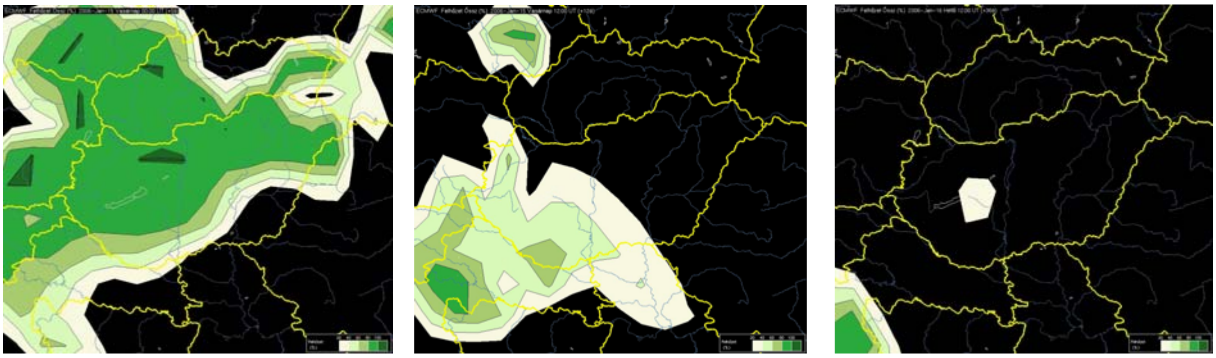


Fig. 20 ECMWF total cloudiness forecast, 15 January 00 UTC+00, 12, 36

Looking at temperature profiles for Budapest, it can be seen that in the ECMWF analysis the bottom of the inversion layer was closer to the surface. In the +12 hour forecast, the inversion layer shifted to the ground and the relative humidity decreased near the bottom of the real inversion layer, below 900 hPa. Obviously, the wrong cloudiness forecasts led to wrong temperature forecasts. Error was about -3 degrees in minimum temperature.

4. References

Hirsch, T., 2006: Investigating and forecasting heavy precipitation events in winter in Hungary using ERA-40 and ECMWF Medium-range Deterministic and Ensemble weather forecasts. *PhD thesis* (in Hungarian).

Szintai, B. and **Ihász I.**, 2006: The dynamical downscaling of ECMWF EPS products with the ALADIN mesoscale limited area model: preliminary evaluation. *Időjárás* 110, 253-277.

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Varga, L., Korényi, Z. and **Hirsch, T.**, 2006: Prediction of Balancing Energy in wind generation using Probabilistic Weather Forecasting. *WSEAS Transactions on Power Systems*.