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The first attempts at the radar echo prediction in the Czech weather radar network

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Abstract. To satisfy the increasing number of user requests for the radar echo prediction data, several possible methods of prediction have been studied in the Czech republic. A future implementation of these methods in the operational processing of the Czech weather radar network (CZRAD) data is expected.

The maximum radar reflectivity composite with 1km horizontal resolution covering the whole territory of the Czech republic is used for radar echo predictions based on different wind field data. Wind field data, crucial point of the radar echo prediction, are calculated using three different methods:

1. COTREC (continuity tracking of radar echoes by correlation)
2. wind field derived from the geopotential at 700 hPa calculated from the local NWP model forecast (ALADIN)
3. comparison of two consequent radar images based on Wavelet Transform Decomposition.

Predicted radar images are compared with the real measured radar data. Prediction methods are compared among themselves and also with persistence forecast.

The prediction scheme and wind field calculation methods are described. First results of the comparison methods are presented.

1 Introduction

The weather radar data have become the basic meteorological information during the last 10 years. Together with the increasing number of radar data applications, requests for prediction of radar data increase enormously.

For the evaluation of radar prediction methods, the maximum radar reflectivity composite field with a 1 km horizontal resolution has been selected. This composite covers the entire territory of Czech republic together with its relatively big surroundings. The 1 km horizontal resolution ensures a better interpretation of radar echoes. The time interval between 2 consecutive radar images is 10 min. (Novak (2000),Novak and Kracmar (2002)).

The concept of our prediction software was designed to be as modular as possible and format compatible in order to be integrated into the CZRAD operational data processing in the near future.

2 Radar echo prediction

The prediction is principally divided into 2 main parts. The first one is the calculation of the motion wind field and the second one is the time extrapolation of radar echo using this motion field.

The motion wind field calculation is the crucial part of the radar echo prediction and the final result is most influenced by precision and stability of the wind field used. The motion field should be smooth enough and, simultaneously, distinguishing the motion difference of storms. That's why 3 different methods of wind field calculation have been tested (COTREC, ALADIN and WAVELET).

2.1 COTREC method

The COTREC method is based on the well known method described, e.g., by Zgonc and Rakovec (1999) or Mecklenburg et al. (1999). Wind field is searched by comparing two consecutive radar images using some similarity criterion. The mean absolute difference was used in this work.

At first the mean motion wind vector over the whole radar image is searched. The latest radar image is compared with the previous one shifted by a different number of pixels along the X and Y axis. For each shifted image the mean absolute error is calculated. Translation with the lowest error

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is taken as a mean motion wind field (velocity is calculated from known shifts along the X and Y axis and known time interval between 2 radar images).

After that, the radar image is divided into 6 smaller boxes and for each box the mean motion wind vector is found in the same way again. If the wind field vector cannot be found in some box, because of a small number of pixels covered by radar echo, the mean motion vector for whole image is substituted.

Each of 6 boxes is again divided into 25 smaller boxes (44×44 km) and corresponding motion wind vectors are investigated. To reduce unwanted high variability of motion vector in the smallest boxes, the motion vectors are checked if they are lying within a predefined interval around the mean motion vector from the higher box (if not, the mean motion vector is used instead).

After the vector calculation in all boxes, the successive over-relaxation (SOR) algorithm is applied to the motion wind field to smooth the final field (wind field is modified to fulfill the continuity condition).

Finally the wind field is recalculated into array with the size and spatial resolution corresponding to the radar image (1 km horizontal resolution) using the bilinear interpolation (see Fig. 1).

2.2 ALADIN method

The main idea of NWP method is that the cloud motion is controlled by air mass flow at approx. 3-5 km above sea level (ASL). That's why the geopotential at 700 hPa (cca. 3 km ASL) forecasted by the local area NWP ALADIN model is interpolated into the radar image size and resolution and then recalculated into motion field using the geostrophical approximation.

The extrapolation based on the ALADIN motion field is a simple but robust method. It cannot take into account the propagation of convective cells, but may help mainly in case of large-scale stratiform precipitation (it is insensitive to the bright-band and radar-horizon artefacts in radar images) and when the radar echo is at the border of radar coverage.

More information about ALADIN NWP model can be found on its web pages.

2.3 WAVELET method

The last tested method is based on a new approach, namely the hierarchical multidimensional wavelet analysis.

Similarly to the COTREC method, it uses the comparison of 2 consecutive radar images to find the motion wind field, but instead of minimalizing differences between shifted boxes, radar images are decomposed into subspaces using the wavelet transformation and wind field is then investigated by calculation of the decomposition similarity criterion at several different detail levels. The wind field calculated at a coarse level propagates into a more detailed level and there is newly evaluated.

Because of high variability of the motion wind field at the final (most detailed) level, similar algorithms as in the COTREC method (velocity interval where velocities calculated at detailed levels should lie, the SOR smoothing) had to be applied.

For more information about the WAVELET method, multi-dimensional analysis and fast wavelet transform algorithm refer to Walder (2001).

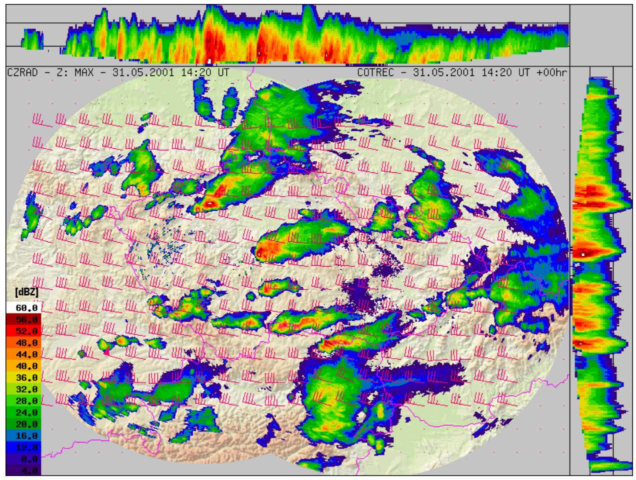

Fig. 1. Example of the motion wind field calculated by COTREC method overlayed over corresponding CZRAD composite of maximum reflectivity field.

2.4 Time extrapolation of radar echo

Time extrapolation of radar echo is based on the method of backward trajectories (for each pixel of a forecast image, the corresponding pixel in the starting radar image is searched for).

Two basic assumption are made during the extrapolation; motion wind field is considered to be constant in time and the growth/decay factor of radar echo is not applied. The COTREC and WAVELET methods are able to calculate the growth/decay factor but it seems that it doesn't improve the forecast. The time extrapolation was calculated up to 90 minutes.

3 Comparison

The radar echo prediction methods were tested on several cases of different weather situations (convective/stratiform). In each case the predictions based on all the methods were calculated continuously for at least half of the day to check the time variability of the forecast quality. The forecasts were also compared with persistence forecasts (the starting radar image is used unchanged as a forecast) to compare not only the individual forecasts but also to find if they really improve the radar information. Examples of radar echo forecasts in severe convective situation based on the different methods are shown in Fig. 2.

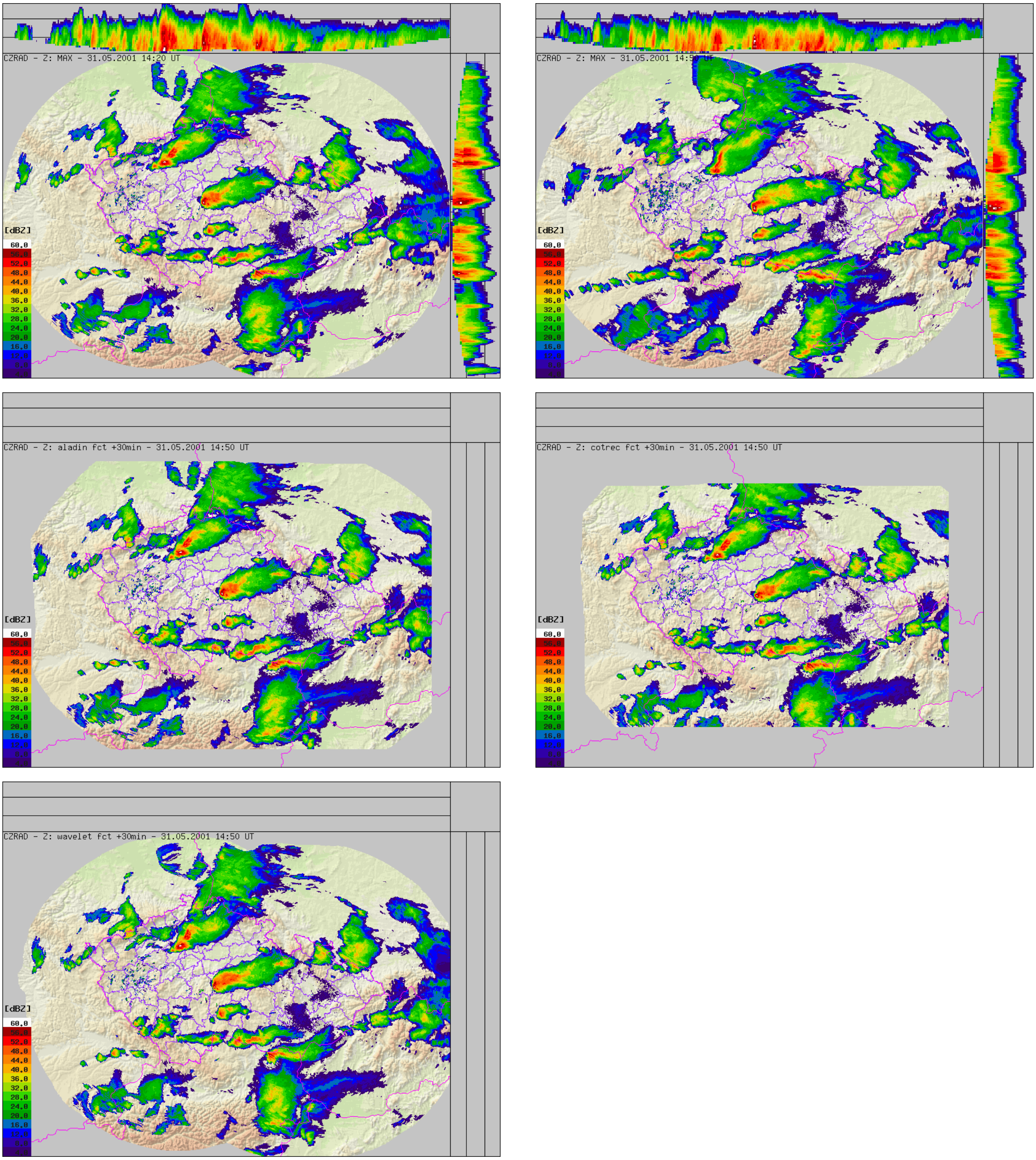

Fig. 2. Examples of 30 min. radar echo prediction based on different motion wind fields (severe convective situation from 31 May 2001). The top left figure shows starting maximum reflectivity field (14:20 UT – persistence forecast). The top right figure shows maximum reflectivity field from forecast time (14:50 UT – true). The middle left figure shows forecast based on the COTREC method (forecast for 14:50 UT). The middle right figure shows forecast based on the ALADIN method (forecast for 14:50 UT). The bottom left figure shows forecast based on the WAVELET method (forecast for 14:50 UT). The different areas of predicted radar images are caused by the different wind field calculation algorithms; the comparison of prediction methods should be done inside the territory of the Czech Republic. Borders of Czech districts are represented by violet lines.

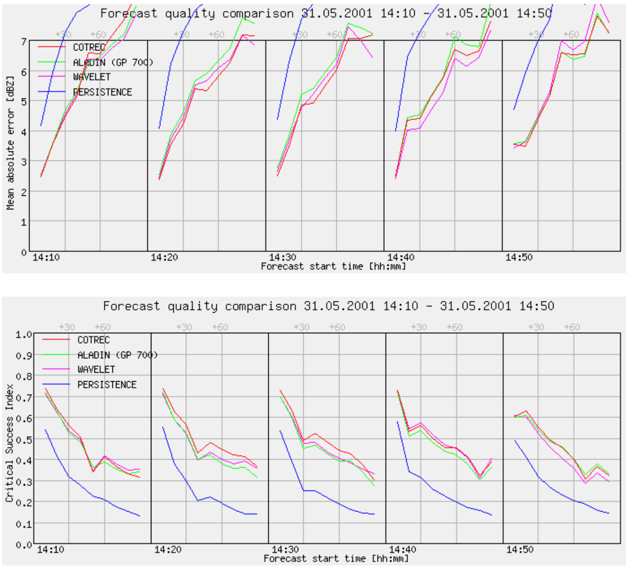

Fig. 3. Example of forecast quality comparison based on mean absolute difference (top) and critical success index of 12 dBZ forecast (bottom)

All forecasts were compared with "true" radar imagery in terms of root mean square error (RMSE), mean absolute error and quality indexes (critical success index, probability of detection, false alarm ratio, ...) of some dBZ level forecast (12, 24, 36 dBZ). Examples of mathematical forecast comparisons are shown in Fig. 3. The subjective meteorological comparison was very important too.

The comparisons showed the following results

– All forecasts methods show improvement of radar information – they are better than persistence forecasts.

– A decrease in the forecast quality with time is similar for all methods. In convective situations, the usable information seems to be up to 30 min. (in some cases up to 50 min. - organized convection), in some stratiform cases the forecast can be used up to 90 min.

– In most cases, the ALADIN method is slightly worse than COTREC or WAVELET, but it can help if we do not have any previous radar image or when the radar echo is at the borders of the radar coverage. It is also insensitive to the different artefacts in radar images.

– COTREC and WAVELET seem to have approximately the same precision. For both methods, a tuning of parameters (sizes of boxes, width of interval where the motion vector of the smallest boxes should lay, minimum number of pixels with radar echo in the appropriate box to start calculations) is very important.

– ALADIN method has significantly smaller HW requirements than COTREC and WAVELET methods. The WAVELET method is more time-consuming than COTREC, but this depends on initial settings (number of boxes (levels), size of area where the displacement vector is searched).

4 Conclusions and outlook

The preliminary study of radar echo prediction usability showed that all three methods can improve radar information comparing with the persistent forecast. In the operational nowcasting, the methods should be used together (at least both ALADIN and COTREC) and also with knowledge of live meteorologists.

This study has been limited to the prediction of radar echo propagation only. At present echo development prediction (the growth/decay factor calculation) doesn't impove the results; it should be studied in more details in the future.

In the future, mainly the COTREC and WAVELET method should be tested on more situations in order to tune their parameters. Then they could be integrated into the CZRAD operational data processing and visualization.

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