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Czech weather radar data utilization for precipitation nowcasting

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Abstract. The precipitation nowcasting based on weather radar data is very often requested by meteorological users. To satisfy these requests, several possible methods have been studied in the Czech Hydrometeorological Institute (CHMI) in several last years. Based on these studies two methods were implemented into the operational processing of the Czech weather radar network in the 2003. The implemented methods are:

1. COTREC (continuity tracking radar echoes by correlation)
2. radar data prediction by wind field derived from the geopotential at 700 hPa calculated from the local NWP model (ALADIN)

The full nowcasting system consists not only of the prediction algorithms, but the prediction results have to be delivered to the users as fast as possible and moreover the users have to have possibility of precise geographical localization of predicted phenomena namely in convective situations. Therefore the results of prediction algorithms are implemented into web-based viewer (JSMeteoView) that has been developed in the CHMI Radar department. At present, this viewer is used by all CHMI forecast offices for versatile visualization of radar and other meteorological data (Meteosat, lightning detection, NWP LAM output, SYNOP data) in the Internet/Intranet environment with a strong support for detailed geographical navigation.

The operational implementation of nowcasting system will be described in the presentation. Preliminary results of the prediction algorithms will be discussed.

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1 Introduction

The Czech Weather Radar Network (CZRAD) is operated by the Czech Hydrometeorological Institute (the national weather service of the Czech Republic). It serves to the national and military weather services, operational hydrology, aeronautical users (air traffic control) and also several other companies (Czech TV, road maintenance, insurance companies, mobile phone operators, ...). Radar data became an important tool for different hydrological and meteorological research projects.

Several severe weather events (floods, flash floods, hail, tornadoes) that occurred on the territory of the Czech Republic within the last decade highlighted the importance of the radar measurements and their utilization in nowcasting systems.

2 Czech Weather Radar Network

The Czech Weather Radar Network consists of two Doppler C-band weather radars [Gematronik Meteor 360 AC with RAINBOW 3.1 software – in operation since 1996, and EEC DWSR-2501C with EDGE software 4.88 – operated since 2000], which cover the entire area of the Czech Republic by volume scans in 10-min. update rate up to 256 km range (Fig. 1).

Full volume scan is combined from two 5-minute subscans (see Fig. 2). Presently, subscans are used only by the Air Navigation Services of the Czech Republic that requires data as fresh as possible. Other users use the combined 10-min. volume scan that consists from 16 elevations (0.1°–34.6°) and enables good vertical resolution of radar data needed mainly by operational hydrology and synoptic meteorology. Subscan combination resulted also into increased recency of the 10-minute volume data because the most important low elevation data are taken from second subscan.

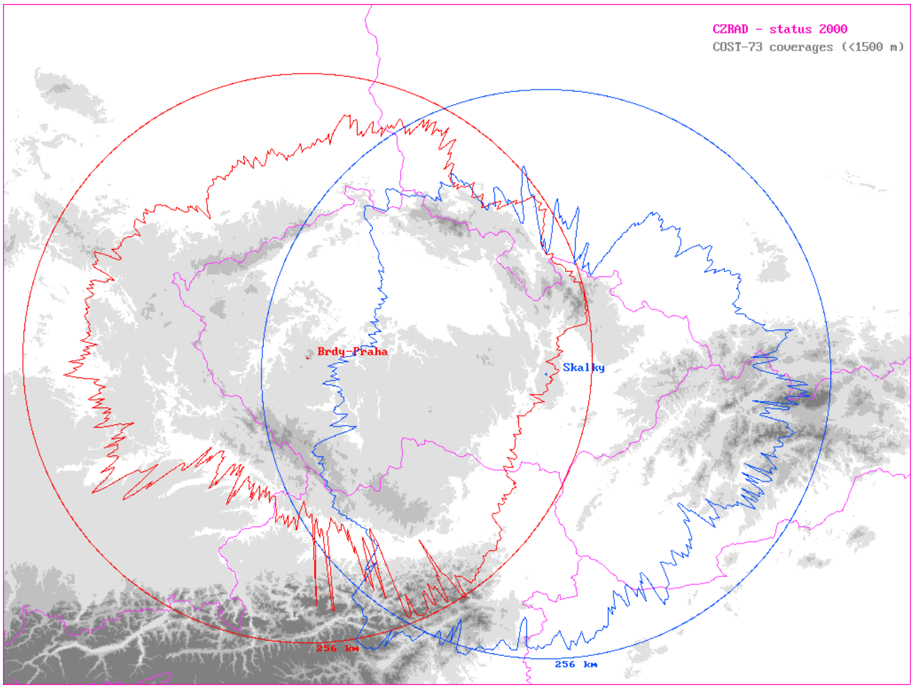

Fig. 1. The maximum coverage of the CHMI weather radars (circles) and coverage for precipitation estimation according to recommendations of the project COST 73 (the lowest usable beam 1500 m above ground level).

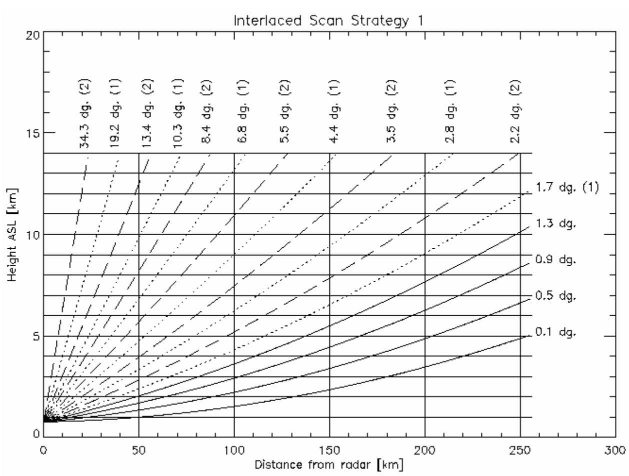

Fig. 2. The interlaced scan for CZRAD network with repetition of 4 lowest PPIs. Repeated elevations are denoted by solid line, other elevations are dashed and labeled by the number of subscan (1 or 2), (Novak and Kracmar, 2002).

Moreover, very important for fast data delivery to the end-users was establishing (in cooperation with the Czech Army) of the 2Mbit/s data connections between both radars and processing center in Prague-Libus. Volume radar data processing, initially done by the vendor software, has been upgraded by in-house software package RVD/RPD which satisfies the increased requirements on output radar products (Novak and Kracmar, 2002). This software enabled the 1 km horizontal resolution products to become a new operational standard. This better spatial resolution offers the possibility for more sophisticated studies of radar echo structures (mainly convective storms) than the 2 km resolution used previously.

The fast data transfer together with the optimisation of the processing scripts (minimizing processing dead times, faster calculation algorithms) significantly increased the availability of radar data to the user. The radar data are available to the users in the first minute after the end of the 10-min. measurement, in comparison with approx. the fourth minute in the old processing.

3 Radar echo prediction

Delivering of the most recent data available to the user is the first very important step in building of a nowcasting system. For certain applications it can be enough, but for most cases prediction of examined phenomenon is required. For radar echo nowcasting, several prediction methods were tested during the last years (Novak, Walder and Kracmar, 2002) and two of them (COTREC and ALADIN) were implemented into operational processing of The Czech Weather Radar Network in the beginning of 2003.

The maximum radar reflectivity composite field with a 1km horizontal resolution has been selected for radar echo prediction calculation. This composite covers the entire territory of the Czech Republic together with its close surroundings. The 1km horizontal resolution ensures a better interpretation of radar echoes.

Both methods are used for prediction of entire radar image domain and are principally divided into 2 main steps. The

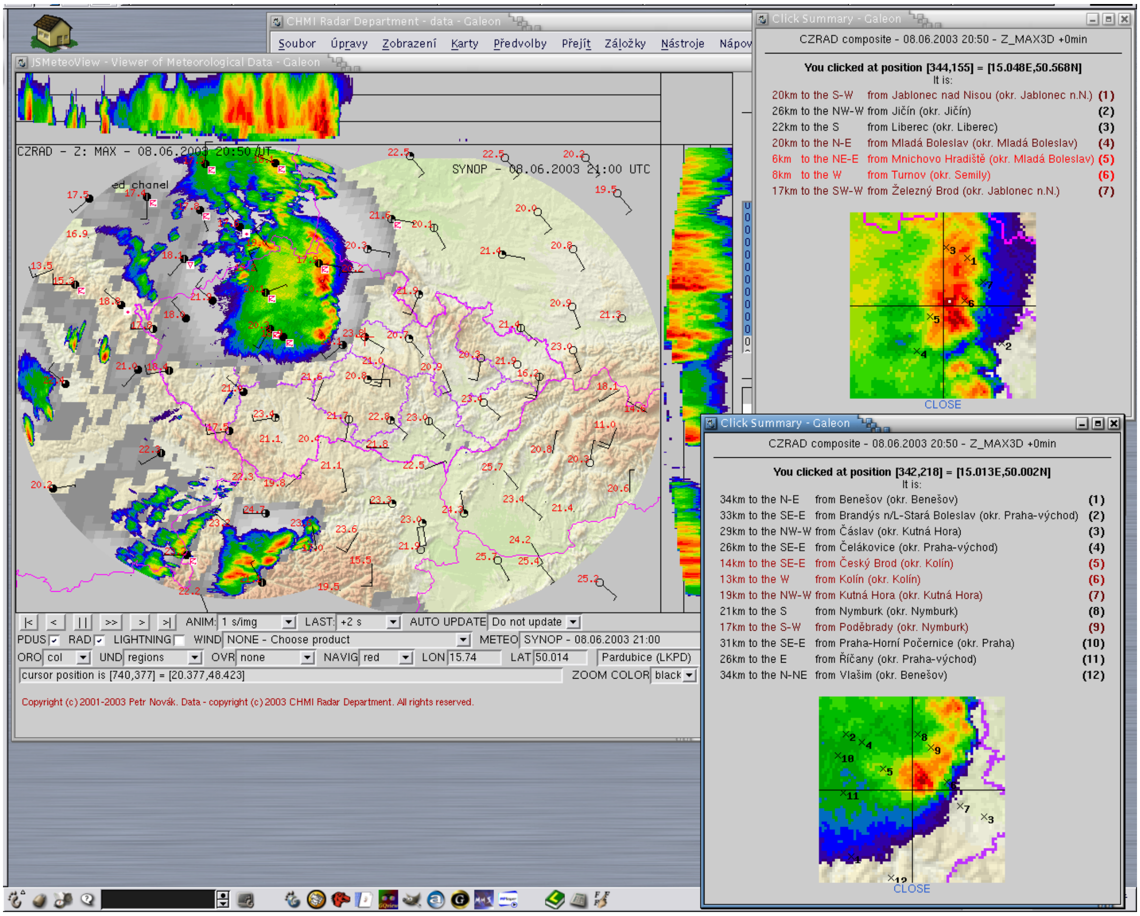

Fig. 3. June 8, 2003 20:50 UTC. The JSMeteoView display: combination of the Meteosat IR image (gray scale), the CZRAD composite of maximum reflectivity field (color scale) and SYNOP observations.

– violet underlay of the Czech region borders

– zoomed radar image and detailed geographical navigation in popup windows.

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 first step, the motion wind field calculation is the crucial part of the prediction that strongly influences the final result. The second step is common for both methods.

3.1 COTREC method

The COTREC method is based on the well known method described e.g. by (Zgonc and Rakovec, 1998) or (Mecklenburg et al., 1999). Wind field is determined by comparison of two consecutive radar images using some similarity criterion. A 10-min interval between consecutive radar images and the mean absolute difference as similarity criterion was used here.

The motion wind vector is determined in 3 steps over different radar domains (starting over the whole radar image and finishing with 25 small (44×44 km) boxes). The continuity of the motion wind vector from bigger to the smaller domains is checked to reduce unwanted high variability of motion vector.

After performing the vector calculations in all boxes, the successive over-relaxation (SOR) algorithm is applied to the motion wind field to smooth the final field.

Finally the wind field is recalculated into array with the size and spatial resolution corresponding to the radar image using the bilinear interpolation.

3.2 ALADIN method

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

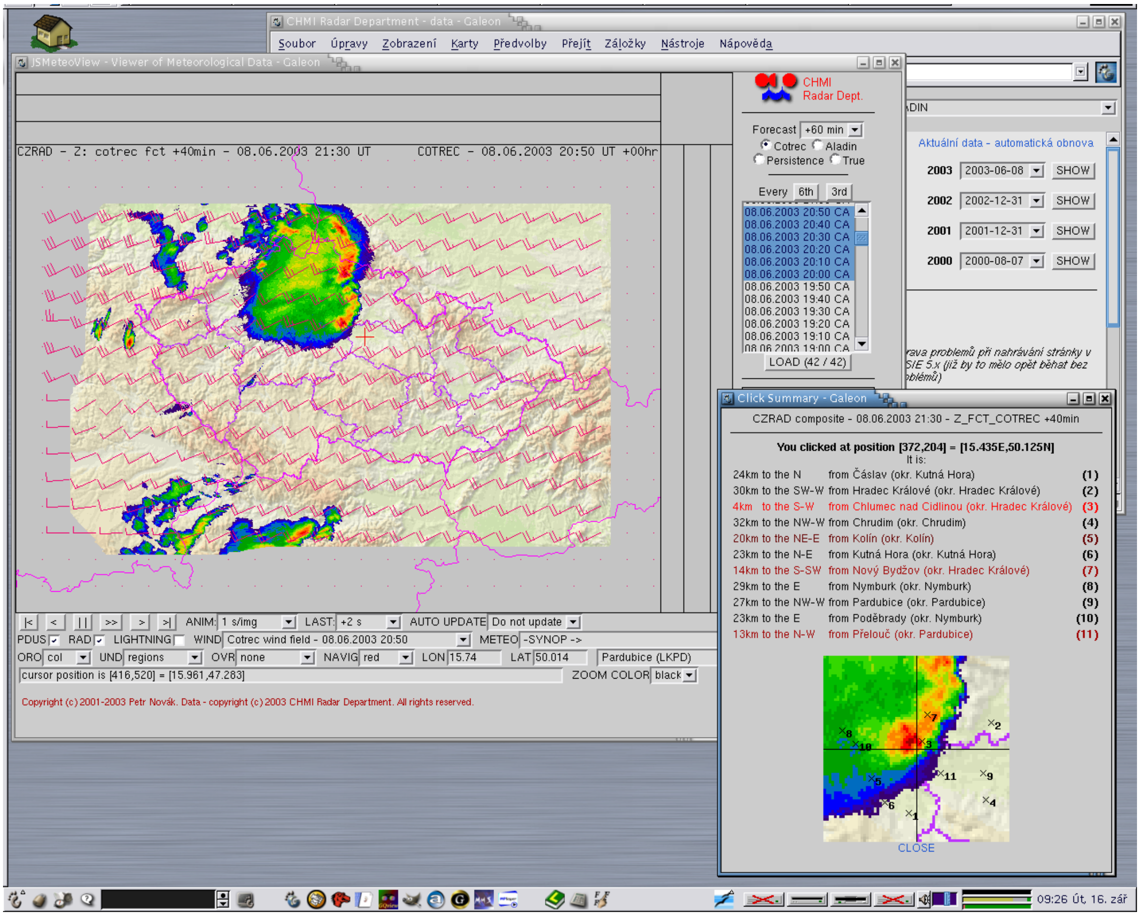

Fig. 4. June 8, 2003 21:30 UTC. The JSMeteoView display: 40 min. forecast of maximum reflectivity field using COTREC method – COTREC wind field used for radar forecast – zoomed forecasted radar image and detailed geographical navigation in popup window.

3.3 Time extrapolation of radar echo

Time extrapolation of radar echo is based on the method of backward trajectories (for each pixel of a forecasted 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 time extrapolation is calculated up to 90 minutes in 10 min. time steps.

3.4 Comparison of prediction method

For selected cases of different weather situations (convective / stratiform) detailed analysis of prediction results was done. In each case the predictions were compared 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).

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

The comparisons showed that both forecast methods show operational aplicability of radar information (they are better than persistence forecasts). A decrease in the forecast quality with time is similar for both methods. In convective situations, the information seems to be usable up to 30 min (in some cases up to 60 min – for organized convection), in some stratiform cases the forecast can be used up to 90 min.

In most cases, the COTREC method is slightly better than ALADIN. In few cases ALADIN method can give markedly worse forecast (if NWP model fails), but it can help if no previous radar image is available or when the radar echo is present at the border of the radar coverage. This method is also insensitive to different artefacts in radar images (the bright-band and radar-horizon artefacts).

Fine tuning of COTREC parameters (sizes of boxes, width of the 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 for good results.

4 Data visualization

To gain the best benefit from the recent and/or predicted radar data, these have to be delivered to the user as fast as possible, and moreover the user needs to have a possibility of precise geographical localization of predicted phenomena, namely in convective situations.

In order to fulfill the above mentioned demands, development of web-based viewer of radar data (JSMeteoView) started in 2001. This development still continues, and at present also other meteorological data (Meteosat, lightning detection, NWP LAM output, SYNOP data) can be visualized in this system (Novak and Kracmar, 2002). Radar echo prediction data were implemented into this viewer soon after start of its operational calculation as well.

JSMeteoView enables versatile displaying of individual data sources or their combination in modern internet browser (Gecko-based browsers Mozilla/Netscape 6.x or Microsoft Internet Explorer 5.x/6.x) independently of the operation of system (Windows, LINUX/UNIX, MAC OS). Presently it serves as basic visualization tool of remote sensing data for the CHMI central and regional forecast offices and also for several external customers.

During the development, big effort was targeted at the detailed geographical navigation that improve localization of predicted events. It includes the possibility of (under-)overlaying of different geographical layers (topography, districts, rivers, catchements, roads, ...), displaying distinctive "navigation cross" (identification of the location for which the forecast is prepared), displaying of geographical information about location under mouse pointer (geographical coordinates, name, distance and direction of the closest city or airport, distance and direction from the "navigation cross"). For even better geographical navigation, data can be zoomed and overlayed by geographical layers (incl. smaller cities).

5 Conclusions and outlook

Interlaced scan strategy, fast data links and in-house volume data processing software RVD/RPD has increased significantly the recency of radar data for users.

Both implemented algorithms of radar echo prediction improve radar information as compared to the persistent forecast, usability of the forecast varies from 30 to 90 minutes depending on type of weather situation. Comparison of both methods and use in combination with skill of forecaster meteorological knowledge is very important in real operation.

The JSMeteoView has been proven to be a very useful tool for operational forecast meteorologists at the CHMI, as well as for research purposes (studies of severe convective storms). After the initial phase of testing and tuning (2001–2002), the JSMeteoView has become the main tool for the operational visualization of the radar and lightning detection network data inside the CHMI as well as in other external locations (contractual users of these data), taking the advantage of platform independence. Accurate geographical navigation together with the advanced data processing enable much better localization of meteorological phenomena.

Plans of future development are targeted at the calculation and evaluation of radar precipitation estimates from predicted radar images up to 1.5 h (2 h) and implementation of "cell" oriented prediction algorithm that could improve quality of the forecast mainly in cases of severe convection. The operational testing of statistical model for nowcasting of 1-hr and 2-hr rainfall developed in the Institute of Atmospheric Physics of Czech Academy of Science (Sokol, Rezacova, Pesice, 2004) is also considered.

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