Data quality of the Romanian WSR-98D weather radar systems

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1. Introduction

Radar measurements are widely used in meteorology and hydrology and nowadays they represent an essential tool both for forecasters and researchers. In Romania, base and derived radar products are used as a primary tool for detection, monitoring and forecasting weather systems, especially when a severe weather phenomenon occurs. Furthermore, radar data is used in the nowcasting operational chain as an important part of warning decision and issue in case of severe weather events, in hydrological applications, as radar information by various type of users.

Therefore, severe weather warnings are mainly based on radar data provided by weather radar systems components of Romanian Doppler Weather Radar Network. The network consists of 8 Doppler weather radars, 3 C-band (EEC-2500C and Gematronik METEOR 500C) and 5 S-band WSR-98D type, all equipments being capable to provide detailed information about the sampled cloud systems. Radar products users and particularly nowcasting forecasters need to be aware of area coverage, beam blockage and quality of data used. Data quality refers to a wide variety of “problems” starting with signal processing, statistics scan strategy, hardware and software calibration, ground clutter, beam blockage or anomalous propagation. Data quality can be assessed also in relation with the application in which the radar data are integrated (i.e., rainfall estimates).

Romania has a substantial variation in its terrain and many other factors influencing the airflow dynamics. The hilly and mountainous regions are strongly affected by floods and flash floods, all areas being subject to diverse conditions ranging from severe thunderstorms with heavy rain, strong winds and hail in summer, to heavy snowstorms in winter season (Ioana et al., 2003). Comparing with the plains, high terrain induces a big percent of mesoscale phenomena including generation of heavy rainfall that further can generate flash floods on small area basins with small response time. Consequently, real-time detection and monitoring of heavy rainfall in areas with high topography is essential for warnings and assessment of hydrological impact such phenomena (Pellarin et al., 2002).

However, in mountainous regions radar rainfall estimation is a very complex process and the quality of estimation is influenced by many factors including radar location. The complexity occurs as a result of two major effects: partial or total beam blockage (Brown et al., 2002; Bech et al., 2003; Wood et al., 2003; Shipley et al., 2005; Krajewski et al., 2006) and microphysics and precipitation dynamics in regions with high terrain (Rotunno and Ferreti, 2001; White et al., 2003; Neiman et al., 2004).

2. Dataset and methodology

In this study we utilize two different types of data: Digital Elevation Model (DEM) with horizontal grid resolution of 1x1 km data and base reflectivity radar data. Volume radar data was not available for longer periods, thus results were not included in this study. DEM data use a geographic projection and a datum of the World Geodetic System of 1984 (WGS84). Beam blockage algorithm uses terrain data in Universal Transverse Mercator (UTM) projection, therefore DEM was resampled and reprojected.

The reflectivity data used were level III files, generated every 6 minutes using VCP-21 scan strategy. This study presents the results of investigations done for two WSR-98D radar locations, Bobohalma - located in the center of the country, and Medgidia - located in the southeastern part next to Black Sea (Fig. 1).
Figure 1. Romanian National Doppler Weather Radar Network

Scanning strategy used by the WSR-98D radar systems operational in Romania is the same for each of the components with elevation angle values starting from 0.5° and increasing with a step of 0.95° for the first four elevation angles. When applied to radars operating in different regions (i.e., mountainous, plains) this can lead to a number of issues due to radar beam propagation, which is determined by the vertical structure of atmospheric temperature, humidity and pressure (Doviak et al., 2000). Also, trajectory of radar beam is sensitive to the atmospheric conditions near the radar location. Under certain conditions, radar beam can deviate from its “standard” propagation and may duct towards the ground, resulting in anomalous propagation echoes (Doviak and Zrnic, 2006).

When part or entire radar beam hits an obstacle, power decreases due to absorption and scattering processes. Part of the beam returns to the radar while the part unaffected by the obstacle continues to propagate, and if it meets a storm, it will result in rain echoes. In effect, the result is an erroneous quantification of rainfall (Krajewski et al., 2006). In this study, radar beam blockage, probability of detection and cumulated reflectivity maps are calculated for the period June-August 2009.

3. Results

Radar energy is sent into atmosphere in the form of a narrow electromagnetic beam with the distribution of power perpendicular on antenna axis (Doviak and Zrnic, 2006). Radar beam power loss was calculated utilizing the algorithm described in Delrieu et al., 1995. The code integrates the DEM available information together with specific radar functional parameters, resulting in a 2 dimensional beam blockage map.

For display and interpretation of results, GIS software is used. Maps were calculated for every radar site and visualized with ArcGIS software package which permits overlaying of beam blockage grids, probability of detection (POD) and average reflectivity over terrain data. Beam blockage, POD and average reflectivity are very good explained by terrain features, concluding that GIS techniques are feasible for determining radar location and its scanning strategy.

For every radar location aforementioned, we will present maps illustrating the topography, beam blockage, POD and averaged reflectivity over a 3 months period. All the elements presented can provide a set of instruments for visual and physical interpretation of issues occurring within radar coverage area, in terms of beam blockage and rainfall detection and estimation.

Next, only the results for Bobohalma WSR-98D radar systems are presented. Bobohalma WSR-98D radar is located in Transilvania, Mures county, in the center of the country, and is surrounded by mountains (Fig. 1).
Mountainous region is extending from a distance of approximately 70 km to 230 km in the northern part of the coverage area. The most significant blockage is present between 150° and 170° azimuth angles, with power loss of more than 80%, for the 0.5° elevation angle (Fig. 2). High value of power loss is present on 280° azimuth as well, with a value of over 70%. Bobohalma radar is experiencing more blockage on other sectors of azimuths, but the percent has smaller values. Within 150°-170° sector, the highest peak from Romanian Carpathian Mountains is present, Moldoveanu Peak, with a height of 2544 m. The focal point of antenna is at a height of 559 m ASL, resulting in a level difference of approximately 2000 m between this and Moldoveanu Peak. The height of beam center at the location of the peak is approximately 1800 m, resulting in a severe beam blockage.

Figure 2b illustrates the POD of the 10 dBZ echoes in case of Bobohalma radar, for the first angle of elevation (0.5°). The map was calculated using level III base reflectivity data for the period June–August 2009, setting the detection threshold for reflectivity at 10 dBZ. POD values are situated within 20–40%, with significantly great value in areas where high terrain is present (90–100%). These values appear as a result of beam–terrain interaction, fact that strongly influence the quality of sampling in the respective areas. Small values of POD (0–20%) can be observed at distances greater than 100 km from radar, due to the fact that beam height is increasing with distance from radar.

Another method for assessing the quality of radar data is by calculating the cumulated reflectivity maps. Figure 3 illustrates this type of map, calculated for Bobohalma WSR-98D radar, using the same dataset as for calculating the POD. One can observe a homogenous distribution of reflectivity values (20–30 dBZ) within almost all coverage area.
This can be a good indicator that, for the studied period, there are no preferential movement paths of storms. Maximum value is 35 dBZ and corresponds to areas where high terrain is present, therefore must be considered when assessing the reflectivity field or using within various algorithms.

For the period studied, one can observe a good correlation between beam blockage, POD and cumulated reflectivity maps. Areas where blockage is present are evident and can be identified and used in future research studies. The best correlation is present within the area between 150°–170° azimuth angles, where the highest mountain peak is present.

4. Conclusions

The present study was based on assessing the quality of radar data by calculating radar beam blockage maps using GIS techniques. Beam blockage was correlated with actual measurements of radar systems, represented by the POD and cumulated reflectivity maps. In this paper, only the results for Bobohalma radar are presented, radar site which is experiencing the most severe beam blockage. It is clear that geographic location of this radar has influences on data quality, by presence of the surrounding mountains. The results show a good correlation between methods and provide useful information about radar data sampling over the respective area.

By utilizing the GIS techniques, one can obtain precise information about the location where the blockage is present. In the same time, they offer a physical interpretation of the effects of beam blockage on data quality and rainfall estimation. Nevertheless, assessing the radar precipitation estimation does not represent the goal of this study. Future detailed research can be done in this direction.

Radar studies based on methodologies using GIS techniques can be a very powerful operational tool and can increase performances of rainfall estimation algorithms. DEM grid resolution plays an important role and higher the resolution more accurate the results. This is, however, limited to technical and processing capabilities of the used equipment.

References


