4.11 RADAR DATA QUALITY – THE CHALLENGE OF BEAM BLOCKAGES AND PROPAGATION CHANGES

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1. BACKGROUND

Radar-based short-range forecasts of precipitation require high quality radar data. Ideally, we want to know the precipitation rate in each grid cell together with the distribution of the error. A distinction should be made between cells free of precipitation and cells where no precipitation has been measured for reasons like beam blockages, attenuation, or beam overshooting.

Precipitation data from radar is subjected to a large number of uncertainties. When converting radar reflectivity to precipitation rate, we assume that the vertical extension of the measurement volume is known, and that the volume is homogenously filled with raindrops. This assumption is rarely fulfilled. The operational experience in the Nordic countries has shown that effects related to the vertical reflectivity profile and beam blockages are the main challenges in quantitative precipitation estimation (http://nordrad.fmi.fi/methods/, Nordic Weather Radar Workshop, 2003). Due to the relatively large distances between the radars in the Nordic weather radar network (NORDRAD), data is often used up to full range (240 km). The echo top heights are low in Nordic climates, especially in winter (Koistinen et al. 2003). Whenever a part of the radar measurement volume is located above the precipitation, the underlying assumption for the Z-R conversion is not fulfilled. Blockages due to obstacles and topography have the same effect. Inhomogeneous beam filling is extremely deteriorating on the precipitation data, and even partial beam blockages may lead to total information loss at low echo top heights.

Even if the volume is filled with precipitation, beam blockages lead to an underestimation of precipitation, especially in situations where the upper part of the volume is filled with snow. The identification of areas with reduced quality due to these errors would therefore be an important improvement of precipitation products. This information could be used operationally in NORDRAD. An operational VPR correction is performed at FMI (Koistinen et al. 2003). No correction for beam blockages is applied operationally in Norway, Sweden and Finland. In the NORDRAD and BALTEX (Michelson et al. 2000) products, these uncertainties are not yet marked and no correction is performed.

Recently, two new NORDRAD quality projects have been suggested to address these challenges (Saltikoff et al. 2004). Partial beam blockages from topography are important to be identified before a VPR correction can be performed. In a first step, a normal atmosphere is assumed and static fields of beam blockages are derived. Later, also situations with anomalous propagation (AP) will be analyzed. Superrefraction and ducting lead to increased surface clutter, which is a problem over sea surfaces since a Doppler filter does not remove sea clutter. Sea clutter is a common problem in the NORDRAD community since many radars are located along the coast, especially in Norway. Ducting over cold and moist surfaces causes clutter because of ducting of a small fraction of the beam (Koistinen 2003). AP has also an effect on the percent of beam blockage and the vertical extension of the measurement volume (Fig. 1). The effect of beam propagation changes on the degree of beam blocking has been investigated by Bech et al. (2003).
The objective of the beam propagation project is to coordinate the work carried out in the NORDRAD member countries to define common algorithms. This paper presents the project plan and first results. The first deliverable of the project is a field for topographic blockages for each radar in the NORDRAD network. The fields can then be used to give quality information or in a next step correct for blockages before the VPR correction and gauge adjustment. For further data processing, this information is useful. Pixels with different degrees of blocking can then be treated in a different way in Z-R transformation or VPR correction. This will increase the accuracy of precipitation estimates in blocked areas.

2. TOOL

The beam propagation model (BMP) was developed at the Norwegian Meteorological Institute (met.no) in 2002 and first results were presented at ERAD 2002 (Gjertsen and Dahl 2002). It simulates the radar’s field of view using information on the scan geometry, a digital elevation model (DEM), and the atmospheric conditions. The topographic correction is based on a model, which computes the lower limit of the volume over each radar data-point for each elevation from a numerical model. A number of beam traces are computed from radiosonde data by the equations

\[
\text{curvature} = \frac{1}{6371} \cdot \frac{dN}{dh} \cdot \cos(\alpha) \cdot 10^{-6}, \quad \text{refraction \_index} = 1 + N \cdot 10^{-6},
\]

\[
N = \frac{77.6}{T} \left( p + 4810 \cdot \frac{\alpha}{T} \right), \quad \frac{dN}{dh} = \frac{\Delta N}{\Delta h}
\]

where \( h \) is the altitude, \( \alpha \) is vertical angle, \( N \) is refractivity, \( p \) is atmospheric pressure, \( T \) is temperature and \( \alpha_v \) is the partial pressure of water vapor. The beam-trace is computed from curvature by a simple numerical method and used in a distributed model where each point is positioned in a cylindrical coordinate system. The topographic data is taken from gtopo30 by the US Geo-service. The DEM is converted to UCS-coordinates in 1x1 km resolution. When a grid point in the DEM is higher than the computed lower limit for the beam in the corresponding radar data point, the pre-calculated beam closest to the topographic data is used as minimum gauge height in that point. All parameters produced by the program can be checked by two-dimensional cuts for any azimuth angle out from the radar.

To avoid instability as the radius increases, the altitude of two neighboring points in one radius-category must be interpolated to match the location of the centre of the points in the next radius-category. This will give a small truncation error in areas with rapid terrain variations. This error can move the indicated blockage one point sideways and make peaks of blockage over narrow sectors disappear as radius increases. If a blockage occurs very close to the radar, blockage from one point will spread to a large area on long distances. If the terrain variation within the area covered by one topographic data-point close to the radar is too large, the blockage pattern behind this point will not be correct. This is a problem due to the resolution of the topographic data and we have yet only tried maps at the same resolution as the radar data.

![Figure 1: BPM output for a cross section towards west on 16.8.2002 (Oslo radar, 0.5 degrees).](image)

The BPM is not suited to detect narrow blockages caused by objects like masts close to the radar. For narrow beam blockages which cannot be modeled by this approach using a DEM, the Finnish
Meteorological Institute (FMI) will use a different approach based on b-scan data.

3. EXPERIMENTS

In NORDRAD, no correction is made for errors deriving from the propagation conditions. For a given elevation and opening angle, the volume and altitude of each radar bin is regarded to be a function of distance from the radar. For the atmospheric variables affecting the index of refraction (mainly temperature and humidity), standard conditions are assumed.

3.1 Beam blockages

For the Oslo radar, the simulated visibility from the BPM is compared to one year of accumulated precipitation to verify the BPM output. The long-term precipitation accumulation gives an idea about the real radar visibility. The simulated visibility from the BPM is calculated using a normal atmosphere as input. The map in Fig.4 indicates to what extent precipitation is visible from the radar. This output from the BPM shows the lower beam edge for the 0.5 degree elevation.

The uncorrected accumulated precipitation sum for the year 2004 illustrates typical artifacts in uncorrected radar precipitation estimates. Precipitation amounts decrease with distance from the radar due to the VPR. In western and northern sectors, there is underestimation due to beam blockages. In the red areas, there is overestimation due to ground clutter. Most of the clutter southeast of the radar is AP clutter. Unlike the other Norwegian radars, no Doppler filter is used at the Oslo radar.

The plot showing the degree of beam blockage (Fig. 2) shows that the maximum blockage is around 50% of the radar beam for normal conditions. The model output and the precipitation estimate do not match perfectly. This may be due to uncertainties in the BPM simulation, differing atmospheric refraction, or an insufficient resolution of the DEM, especially at close ranges. In southern direction from the radar, narrow sectors are blocked by masts. These blockages will be dealt with the b-scan method. The overall pattern matches however well.
3.2 Anomalous propagation

AP may lead to beam splitting, increasing the measurement volume and inducing new errors. Figure 1 shows output from the BPM for a situation on 16.8.2002. A cross section towards west for the Oslo radar is shown. The dashed red line shows the vertical extension of the measurement volume under normal conditions (normal atmosphere and no beam blockages). The blue line shows the vertical extension of the measurement volume for the actual situation, modeled with input from radiosonde measurements at Gardermoen. The red line shows the lower beam edge after the blocking from topography. The example illustrates that the degree of beam blockage is variable depending on the refraction of the radar beam. Especially in situations with beam splitting, the error might be large since the measurement volume is much larger than normal. In Fig. 5, the calculated lower beam edges for the 0.5 degree elevation at radar Rissa are shown for two radiosonde soundings. The figures illustrate how the degree of beam blockage can vary from one radiosonde sounding to the next.

4. FUTURE WORK

The overall aim of the project is to give quality information and apply beam blockage corrections to the NORDRAD data. Fields with the error for each radar in the NORDRAD network, first for standard conditions, then for non-standard conditions will be calculated.

We plan to derive statistics on the frequency of AP conditions from radiosonde soundings. Then, the ability of NWP models (e.g. HIRLAM11, HIRLAM22) to simulated AP conditions has to be investigated. If the NWP model results are acceptable, the forecast fields will be used as input for the BPM and the Radar Simulation Model (RSM) implemented at met.no and the Swedish Meteorological and Hydrological Institute (SMHI), respectively. The performance of the BPM and the RSM to forecast AP will be evaluated. Additionally, the impact of an advanced formulation of RSM’s radar beam geometry will be investigated. This study will also enable us to estimate the frequency of AP situations for planned radar sites. New radar sites can be selected such that sea clutter and beam blockages related to AP can be kept at a minimum. Quality information from VPR and beam blockage algorithms may also enable us to do better compositing in the future.

**Figure 5:** Example of BPM output for AP conditions. Height of lower beam edge for the Rissa radar (Norway) at 0.5 degree elevation modeled with radiosonde data at 00 UTC (top) and 12 UTC (bottom) on 19.4.2004.

**REFERENCES**


