8.7 WEATHER RADAR DATA QUALITY IN NORTHERN EUROPE: BEAM PROPAGATION ISSUES

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1. INTRODUCTION

Radar-based applications in Northern Europe require high quality measurements. In reality, precipitation data from radar is subjected to a large number of uncertainties. Some of the challenges are specified in http://nordrad.fmi.fi/methods/.

The Nordic Weather Radar Network (NORDRAD) is a cooperation between Norway, Sweden, Finland, and Estonia. In this consortium, the identification of uncertainties related to radar beam propagation and the adjustment of vertical profiles of reflectivity have been assigned highest priority. Two projects have been formulated to tackle both challenges and provide common solutions applicable to NORDRAD (Saltikoff et al. 2004). This paper addresses the beam propagation project focusing on topographic beam blocking and anomalous beam propagation (AP) caused by refractivity variations in the atmosphere.

Gjertsen and Dahl (2002) developed a beam propagation model (BPM) at the Norwegian Meteorological Institute. It simulates the radar's field of view using information about the scan geometry and the atmospheric conditions. Topographic data is provided by GTOPO30 which is a global digital elevation model (DEM) with a spatial resolution of 1 km. The BPM is not able to detect narrow blockages caused by nearby objects like masts. Moreover, if the terrain variation close to the radar is too large the blockage pattern will be unrealistic due to the coarse resolution of the topographic data set.

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2. BEAM PROPAGATION

2.1 Standard propagation

When deriving precipitation information from radar observations beam propagation is usually assumed to be ideal. For a given elevation and half power beam width, volume and altitude of each radar bin are regarded to be a function of distance from the radar. For the atmospheric variables affecting refractivity, standard conditions are assumed.

Many radars in Norway and Sweden are affected by topographic blockages because the lowest elevation angle is 0.5°. Inhomogeneous beam filling due to beam blocking is a serious problem when deriving precipitation rates from radar measurements. At high latitudes, where echo top heights generally are low, even partial beam blockage can lead to total information loss, since the upper part of the beam often overshoots the precipitation.

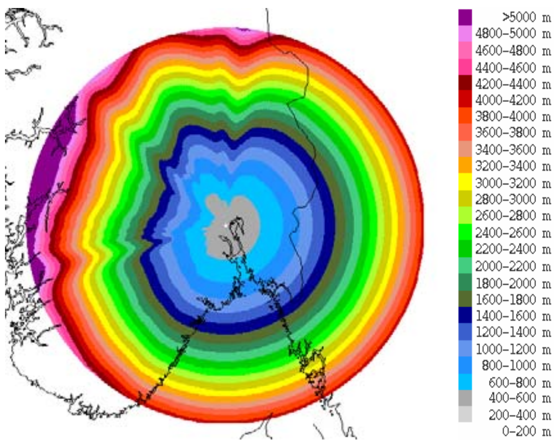

Figure 1: Height of the lower beam edge simulated by the BPM for the radar in Oslo. The elevation angle is 0.5° and the half power beam width is 0.9°.

First, we investigated the impact of topography on beam propagation assuming standard conditions. In this case, BPM's vertical refractivity gradient (VRG) is defined as follows:

$$\frac{dN}{dz} = -43 \exp\left(-\frac{z}{7.36}\right), \qquad (1)$$

where z is the height in km.

We will illustrate the output of the BPM for the radar in Oslo, Norway (59.9°N, 10.4°E, 458 m ASL). Figure 1 shows the height of the lower beam edge simulated by the BPM for standard conditions. The effect of topography is clearly visible in the west and north. Here, the height of the lower beam edge is increased compared to areas at the same distance from the radar e.g. in the south.

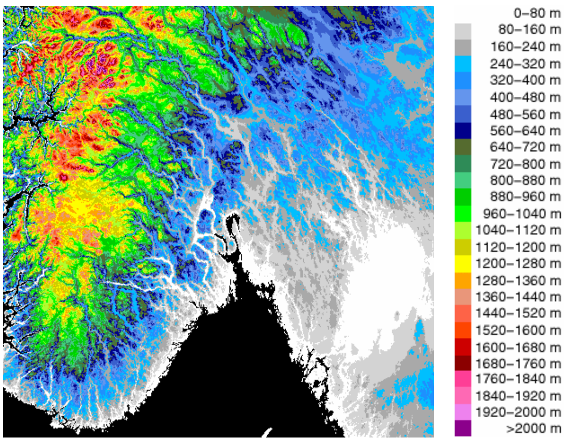

Figure 2: Topography around the Oslo radar located in the center. The length of the square side is 240 km.

This is confirmed by Figs 2 and 3 showing the topography and the degree of beam blockage, respectively. The maximum blockage is about 50%.

We verified the radar visibility simulated by the BPM against radar derived long-term precipitation accumulations because they provide a reasonable first guess of the real visibility. The standard NORDRAD product exchanged between the institutes is a PseudoCAPPI at 500 m height above the radar. This PseudoCAPPI is used for the precipitation accumulation. Since Figs 1 and 3 show beam blockage only for the lowest PPI, pixels close to the radar can not be evaluated. At ranges longer than approximately 40 km from the radar, the PseudoCAPPI is identical with the lowest PPI.

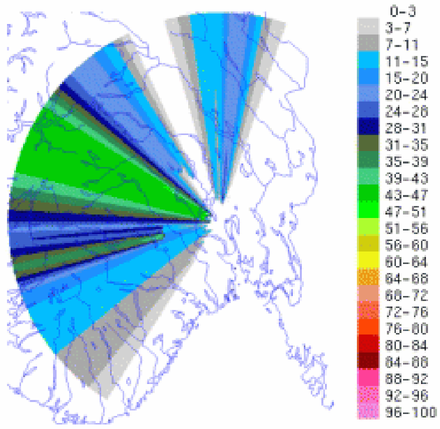

Figure 3: Beam blockage in percent simulated by the BPM for the radar in Oslo. The elevation angle is 0.5° and the half power beam width is 0.9°.

Figure 4 shows the accumulated precipitation observed by the Oslo radar in 2004. Precipitation amounts decrease with distance from the radar because of the geometry. West and north of the radar, precipitation is underestimated due to beam blockages. Overestimation (red areas) is caused by ground clutter and AP, especially in the Southeast. Unlike the other Norwegian radars, a clutter map instead of a Doppler filter is applied for the radar in Oslo.

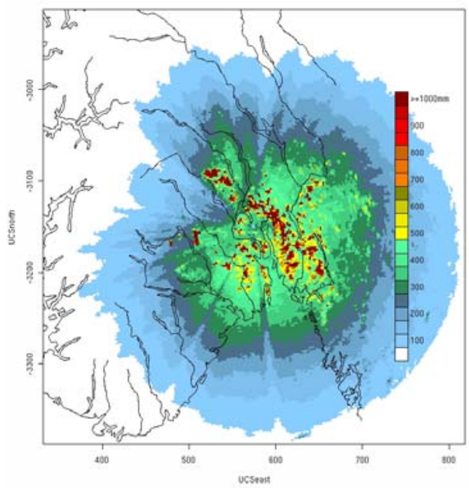

Figure 4: Accumulated precipitation observed by the Oslo radar in 2004.

The simulated (Fig. 3) and observed visibility (Fig. 4) agree mostly. Differences can be explained by (i) inherent uncertainties in the BPM simulation, (ii) differences in the atmospheric refractivity conditions, and (iii) an insufficient horizontal resolution of the DEM especially at close ranges. South of the radar narrow sectors are blocked by masts which can not be handled by the BPM.

2.2 Anomalous propagation

AP echoes are caused by superrefraction. If the refraction of the radiation is strong enough, the radar waves can be trapped in a layer of the atmosphere. This phenomenon is called ducting. Ducting occurs when d*N*/d*z* is equal or less than -157 N-units/km. AP echoes over sea, also called sea clutter, are a common problem in NORDRAD as many radars are located along the coast (Koistinen et al. 2003). Since sea clutter is not static, it can not be removed by Doppler filters. The effect of beam propagation changes on the degree of beam blocking has been investigated by Bech et al. (2003).

In order to simulate AP with the BPM, the atmospheric input need to be changed. Instead of standard conditions, radiosonde soundings or numerical weather prediction (NWP) model forecasts can be used as input for the BPM.

(a) Radiosonde soundings

Table 1 shows average heights for different types of ducts observed at five radiosonde sites in Norway from January 2003 to July 2005.

Table 1: Mean values for surface duct height (SDH), surface-elevated duct height (SEH), and elevated duct height (EDH) derived from five Norwegian radiosonde stations from Jan 2003 to Jul 2005 at 0000 UTC and 1200 UTC. The parenthesized numbers are the corresponding sample sizes.

	0000 UTC		1200 UTC	
SDH	23 m	(1800)	23 m	(2018)
SEH	103 m	(8)	95 m	(8)
EDH	1558 m	(614)	1630 m	(637)

The different types are surface ducts, surface-elevated ducts and elevated ducts (see e.g. Turton et al. 1988 for details). Most common are surface and elevated ducts.

Depending on the geometry of the intersection between the radar scan and the ducting layer (angle of the main lobe, depth of the layer, etc.) the presence of ducts will increase dramatically the number and intensity of AP echoes.

Figure 5 shows the VRG profile derived from the Sola, Norway (58.9°N, 5.7°E, 37 m ASL), radiosonde sounding at 0000 UTC 10 July 2005 and that used as standard in the BPM. The surface-elevated duct in the observed VRG profile is clearly visible.

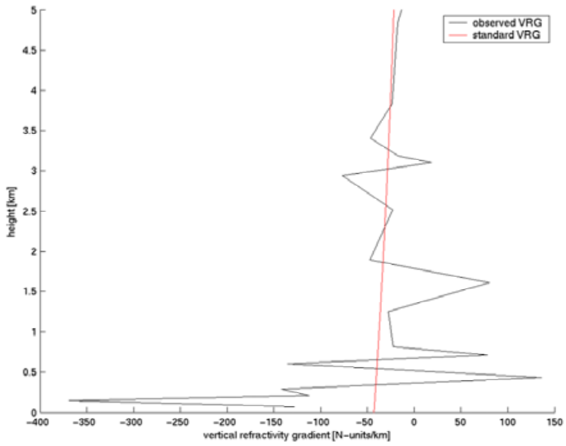

Figure 5: VRG profile derived from the Sola radiosonde sounding at 0000 UTC 10 Jul 2005 (black) and that used as standard in the BPM (red).

Figure 6 shows the height of the lower beam edge simulated by the BPM for the radar in Bømlo at the Norwegian west coast (59.9°N, 5.1°E, 104 m ASL) when using the Sola radiosonde sounding at 0000 UTC 10 July 2005 and standard atmospheric conditions as input. The sector in the east is masked because it is completely blocked at 0.5° elevation. West of the radar, the lower beam edge is below 200 m ASL indicating sea clutter risk (Fig. 6, top).

The 500 m PseudoCAPPI of Doppler filtered reflectivities for the radar in Bømlo at 1900 UTC 9 July 2005 shows sea clutter (at medium range) and echoes induced by coastal mountains (Fig. 7). This corresponds to the BPM output in Fig. 6 (top). At 0000

UTC 10 July 2005 spurious echoes are more difficult to identify because a precipitation band approaching from the Northwest is overlaid.

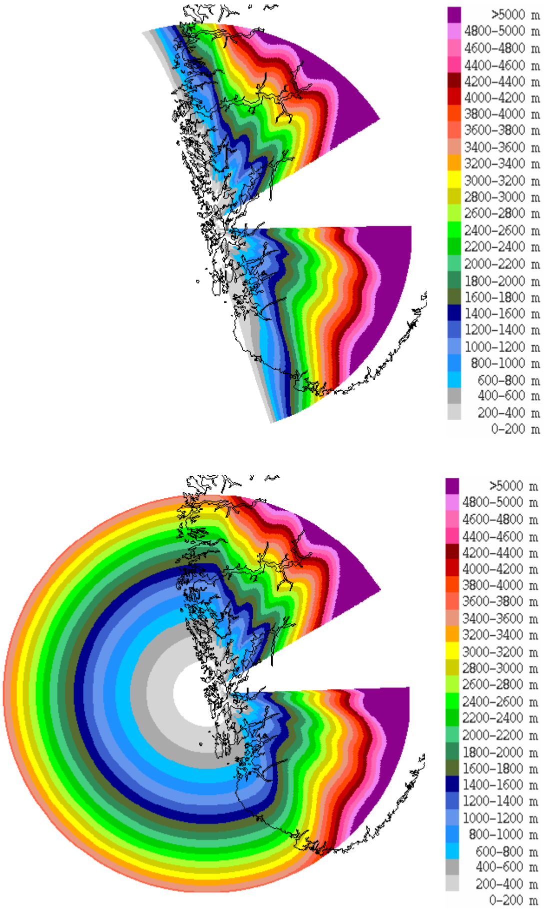

Figure 6: Height of the lower beam edge simulated by the BPM for the radar in Bømlo. As input the Sola radiosonde sounding at 0000 UTC 10 Jul 2005 (top) and standard atmospheric conditions (bottom) have been used. The elevation angle is 0.5° and the half power beam width is 1.0°.

(b) NWP model forecasts

Before using NWP model forecasts as input for the BPM, it needs to be investigated if the NWP model is able to simulate ducting situations at all. At SMHI and some of the NORDRAD member countries the High Resolution Limited Area Model (HIRLAM; Undén et al. 2002) is run operational at 22 km (HIR22) and 11 km (HIR11) horizontal resolution.

The impact of HIRLAM's spatial resolution on the simulation of ducting conditions is examined by Nilsson (2005). He verified the NWP model output against radiosonde soundings and radar images. The study implies that an increased spatial resolution allows a better representation of the VRG. In near future, we will evaluate the use of HIR11-derived VRGs to forecast AP with the BPM.

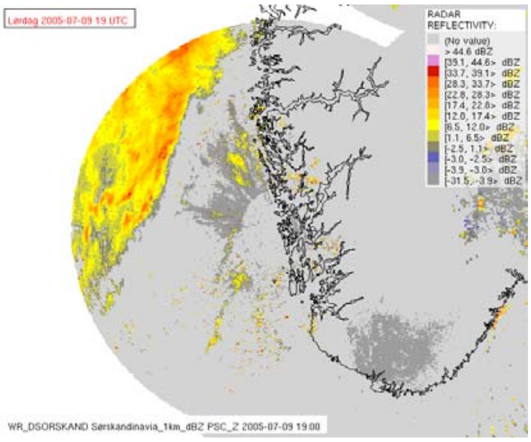

Figure 7: 500 m PseudoCAPPI of Doppler filtered reflectivities for the radar in Bømlo at 1900 UTC 9 Jul 2005.

3. FUTURE IDEAS

In the next stage, a beam blocking correction for standard conditions will be applied to all Norwegian radars using the BPM. Then, corrected and uncorrected annual precipitation accumulations from radar will be compared to gauge measurements. If an improvement is evident, radiosonde data will be used as input for the BPM to assess the effect of beam propagation changes on the degree of beam blockage. We will investigate whether it is sufficient to apply beam blockage correction for normal conditions or whether we can even improve the correction by using temporally and/or spatially variable correction fields.

The BPM also enables 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.

Ideally, we want to know the precipitation rate together with a quality index at each radar pixel

(Michelson et al. 2004). The identification of areas with reduced quality due to beam blocking or AP would therefore both optimize the NORDRAD compositing algorithm and improve the precipitation products (Michelson et al. 2000). The quality indices are also valuable as input for SMHI's Mesoscale Analysis System (MESAN), for NWP models in terms of data assimilation, and for hydrological models. Recently, a new COST action (731) has been initiated dealing with the propagation of uncertainty in advanced meteo-hydrological forecast systems. The operational application of quality information for radars and radar data is addressed in the EUMETNET OPERA program.

REFERENCES

Bech, J., Codina, B., Lorente, J., Bebbington, D., 2003: The Sensitivity of Single Polarization Weather Radar Beam Blockage Correction to Variability in the Vertical Refractivity Gradient. J. Atmos. and Oceanic Technol., **20**, 845—855.

Gjertsen, U. and Dahl, J. I., 2002: Challenges for precipitation estimation in mountainous regions. 2nd European Conference on Radar Meteorology, ERAD publication series, **1**, 250—254.

Koistinen, J., D. B. Michelson, H. Hohti and M. Peura, 2003: Operational Measurement of Precipitation in Cold Climates. In P. Meischner (Ed.), Weather Radar - Principles and Advanced Applications, Springer-Verlag, 78–114.

Michelson, D. B., Andersson, T., Koistinen, J., Collier, C. G., Riedl, J., Szturc, J., Gjertsen, U., Nielsen, A., and Overgaard, S., 2000: BALTEX Radar Data Centre Products and Methodologies. SMHI Reports Meteorology and Climatology No. 90.

Michelson, D., Einfalt, T., Holleman, I., Gjertsen, U., Friedrich, K., Haase, G., Lindskog, M., and Jurczyk, A., 2004: Weather Radar Data Quality in Europe: Quality Control and Characterization. COST-717 working document WDF_MC_200403_1, http://www.smhi.se/cost717

Nilsson, R., 2005: The impact of spatial resolution on radar ducts in numerical models. Stockholm University, Department of Meteorology, 19 pp.

Saltikoff, E., Gjertsen, U., Michelson, D., Holleman, I., Seltmann, J., Odakivi, K., Huuskonen, A., Hohti, H., Koistinen, J., Pohjola, H., Haase, G., 2004: Radar data quality issues in Northern Europe. 3rd European Conference on Radar in Meteorology and Hydrology, ERAD publication series, **2**, 212—215.

Turton, J. D., D. A. Bennets, and S. F. G. Farmer, 1988: An introduction to radio ducting. Meteorol. Magaz., **117**, 245—254.

Undén, P., Rontu, L., Järvinen, H., Lynch, P., Calvo, J., Cats, G., Cuxart, J., Eerola, K., Fortelius, C., Garcia-Moya, J. A., Jones, C., Lenderlink, G., McDonald, A., McGrath, R., Navascues, B., Nielsen, N. W., and V. Ødegaard, V., Rodriguez, E., Rummukainen, M., and R. Rõõm, R., Sattler, K., Sass, B. H., Savijärvi, H., Schreur, B. W., Sigg, R., The, H., and Tijm, A., 2002: HIRLAM-5 Scientific Documentation. Available from SMHI, S-60176 Norrköping, Sweden.