7R.2 Diagnosis of precipitation detection range

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1. INTRODUCTION

Many algorithms and radar system solutions have been developed to maximize the detection visibility of precipitating echoes. However, the longer is the measurement range the larger is the probability that a radar does not detect any precipitation due to total beam overshooting or due to partial beam overshooting and increasing minimum detectable dBZ (Joss and Waldvogel 1990). Rapidly decreasing probability of detection (POD) as a function of range is most common in cold climates where shallow precipitation and weak reflectivities are frequent especially in snowfall (Koistinen et al. 2003). In the worst cases moderate snowfall intensities at ground are detectable only to ranges of 50-75 km. The problem can be severe also in mountaineous regions where beam blocking reduces the visibility, and thus the POD (Pellarin et al. 2000). Although radar meteorologists are well aware of the fact that "invisible" precipitation can exist below the lowest elevation beam, the end users often rely on radar images as a truth up to the nominal measurement range of 250 km shown in the products. As far as we know, no institute estimates and presents operationally the POD of precipitation as a function of range. It should be one of the important real time quality measures at each pixel of a precipitation product from every radar system.

2. Methods

At the Finnish Meteorological Institute we have started to test estimates of POD of ground level precipitation obtained applying three different methods.

The visibility of precipitation (V) can be estimated as a function of range applying the measurement geometry of radar beam, minimum detectable dBZ and high resolution measured VPR from the polar radar data at close ranges to each radar. As a first guess we can assume that the measured VPR approximates well enough the average VPR at all ranges. By using Gaussian beam convolution of the VPR at all ranges applying the known lowest elevation angle we obtain a single value for the maximum distance of detection (Fig. 1). Probability of precipitation detection (POD) at each range is obtained by repeating the convolution procedure for an ensemble of VPRs. The ensemble members can be obtained from the following sources:

(1) Applying old measured VPRs from the same radar. The representativity of VPRs is enhanced by quality weighing each measured individual VPR, diagnosed as precipitation or overhanging precipitation. A typical speed of VPRs is of the order of 10 m/s implicating that an appropriate time window to collect VPRs from a single radar, measuring up to the range of 250 km, is roughly 6 hours. Measured VPRs can be obtained also from the neighbouring radars. The distance between two nearest radars in Finland is usually 150-250 km. In most cases VPR heights don't change dramatically within such distances.

(2) By using climatological VPRs applying the actual freezing level height at each time moment. Such profiles can consist of fixed (average)vertical gradients of reflectivity both above and below the bright band as well as of fixed bright band amplitude and thickness. Climatological VPRs are necessary when no precipitation is detected in the high resolution subvolume near a radar or when the measured VPRs represent clear air echoes.

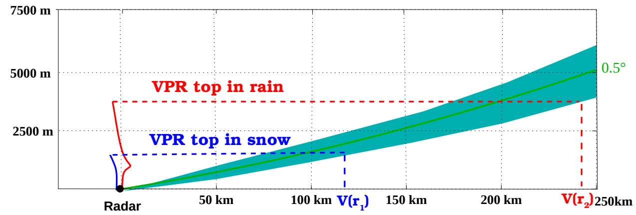

Figure 1: Schematic vertical cross section of a radar measurement. Example vertical profiles of reflectivity (VPR) from rain (red) and snow (blue) are shown on the left, above the radar. Green area is the contributing region of a Gaussian radar beam (precipitation signal larger than the minimum detectable signal MDS expressed in dBZ units). Dashed lines denote the maximum range of detection or visibility (V) of precipitation in the example cases of rain and snow.

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(3) Generating simulated VPRs from the measured VPR by keeping its shape constant but modifying the ground level dBZ according to the observed frequency distribution of the dBZ values at the lowest level PPI, inside the range from which the measured VPR is obtained.

The actually observed POD can be quantified at the ranges where overlapping radar pairs measure the same precipitation area with the lowest elevation PPI (Fig. 2). The close range radar 1 measures almost at the ground

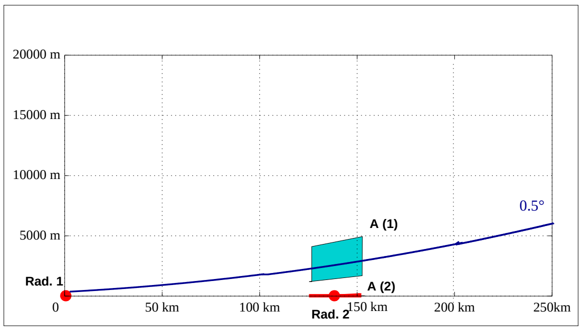

Figure 2: Schematic vertical cross section of overlapping measurements from radars VAN (radar 1) and ANJ (radar 2), denoted as red dots. Red horizontal bar denotes the lowest elevation PPI measurement from area A(2) close to radar 2. The green volume denotes the contributing region of radar 1, denoted as A(1), which is the best available sample of A(2) applying radar 1.

level (which represents well the actual precipitation) the area of precipitation A(1) whereas at the distant of radar 2 it detects only part of the precipitating area A(2). It can be assumed that due to the short distance radar 2 can detect all significant precipitation. In that case the ratio A(1)/A(2) is a measure of POD at the average range r, which is the distance from radar 1 to the center of the compared overlapping subgrid area (Fig. 3).

Real time POD of precipitation as a function of range can be estimated also from the ratio f = A(p)/A(tot), where A(p) is the area of precipitation and A(tot) the area of a circular range belt r2 - r1 from a radar. If the precipitation coverage fraction (f) is horizontally homogeneous the decrease of f as a function of range will measure the quantity POD(r). An axample case is shown in Figs. 4 and 5.

Applying a large sample of POD(r) from the two latter methods and V(r) at all ranges r from the first method, a good correlation between POD(r) and V(r) denotes that VPRs can be used in real time to estimate the actual POD(r). When POD(r) is presented as a quantitative shade underlay on an operational precipitation product the users immediately recognise at least semi-

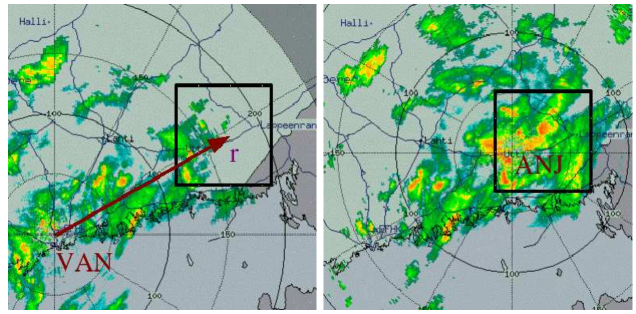

Figure 3: An example of the estimation of POD of precipitation over the rectangular area applying an overlapping pair of radars at the same time moment. Coloured areas denote precipitation exceeding the MDS of each radar. Inside the rectangular area radar VAN detects approximately 22 % of the precipitation coverage detected by the close radar ANJ. The obtained figure is an estimate of the POD of precipitation at range r from radar VAN in the example case.

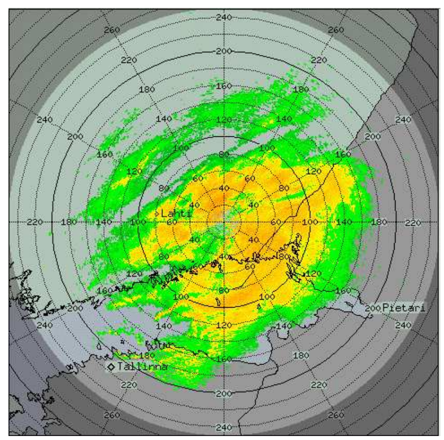

Figure 4: An example lowest elevation PPI image of precipitation with range rings at intervals of 20 km.

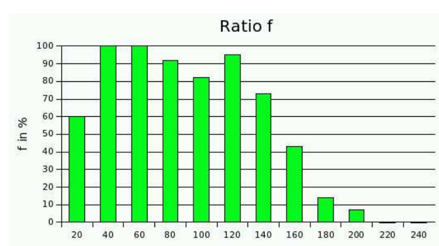

Figure 5: Precipitation coverage fraction (%) as a function of distance in 20 km wide range belts in Fig. 4.

quantitatively the detection probability of precipitation in each pixel of the composite image, Fig. 6. Examples and

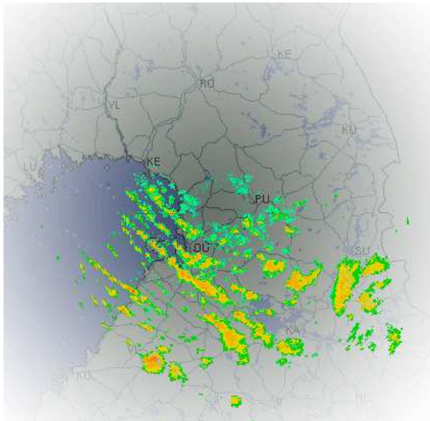

Figure 6: Visualisation example of the probability of detection (POD) of precipitation for customers. A single radar example is shown in which the bacground map darkness is proportional to the POD of precipitation at each range from the radar.

statistics of the obtained PODs will be shown in the actual conference presentation.

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