P15.1 ESTIMATION OF REPRESENTATIVE VERTICAL PROFILES OF REFLECTIVITY IN THE REGIONS BETWEEN RADAR SITES

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1. CHARACTERISTICS OF THE VERTICAL PROFILE OF REFLECTIVITY IN FINLAND

Precipitation in cold climates like that in Finland is quite shallow, in winter frequently only 1-5 km high. Even in summer at ranges of 150-250 km, the lowest elevation beam often illuminates only snow particles. It took 40 years of radar meteorology to admit that in such environments the essential factor in operational measurements at all ranges is not the "local climatological" Z-R or Ze-S but the vertical profile of reflectivity (Zawadzki 1984, Joss and Waldvogel 1990). This is demonstrated well by Saltikoff et al. (2000) in Finland.

As has been shown in many studies climatological VPR or time averaged seasonal, monthly or weekly mean VPR will reduce major part of the bias in gauge-radar comparisons i.e. the radar bias. Vignal et al. (2000) could gain only 10 % more improvement by applying locally averaged hourly profiles in ranges up to 130 km from a radar. In a cold climate, especially in snowfall, the need for higher resolution VPR in time and space is more urgent. The customers applying radar products in real time require more and more accurate estimates of precipitation. In winter e.g. the local road maintenance companies (snow clearance, salting and sand seeding) in Finland make costly decisions of actions based on radar measurements and nowcasting. A correction based on an average long period VPR will not produce the required accuracy. The main reason is the large variability of the height of the shallow VPR in time and space, see Fig. 1.

When the VPR height varies between 1-5 km in winter, the resulting correction at ranges of 50-250 km varies in a much wider range than the respective correction in summer, when the height of a VPR varies typically in the range of 5-11 km in Finland, see Table 1. Therefore we need a real time operational correction of the effects of the vertical profile of reflectivity, responding to the rapid time-space variations in VPR. At longer operational ranges the estimation of local short period profiles becomes a difficult task as the beam-smoothed radar measurement will contain information only from altitudes 2-4 km or higher in the atmosphere, often totally overshooting the layers of snowfall. Thus the estimation of VPR in time and space should apply several sources of information.

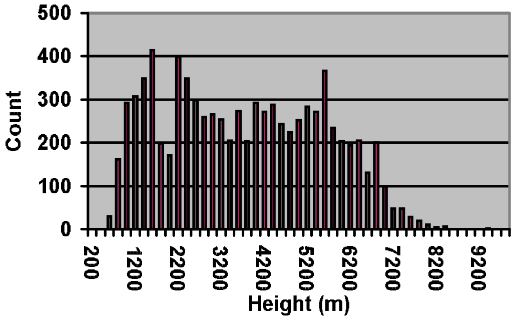

Figure 1: Frequency distribution of the echo top height of 6000 instantaneous vertical reflectivity profiles of precipitation (90 % snowfall) measured at intervals of 15 minutes at 7 C-band Doppler radars in Finland in March 2001. Each profile has been derived from the 3D precipitating bins inside the range of 40 km from a radar. Cases of clutter, elevated precipitation and clear-air echoes (reflectivity at ground level less than -10 dBZ) are excluded.

The first logical step in applying any instantaneous VPR is to perform a quality control and pattern recognition. We have implemented simple tests which diagnose three different types of profiles, consisting of 200 m thick layers. Table 2 shows the classification of the profiles and their frequency in the sample of 6 000 volume scans.

Table 1: The correction (dB) in a radar measurement of surface precipitation due to a typical VPR of variable height in Finland.

Height of VPR (km)	Correction of surface precipitation (dB) at various ranges		
	50 km	150 km	250 km
1	1	49	> 50
3	0	8	> 50
5	0	5	35
7	0	5	23
9	0	5	16

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Clear air echo denotes simply cases in which the ground level reflectivity was less than -10 dBZ.

Table 2: Frequency distribution of classified profiles of reflectivity in a sample of 6 000 3D volume scans in Finland in March 2001.

Type of profile structure	Frequency (%)
precipitation at ground	56
elevated precipitation layer	8
clear air echo	36

All profile types contain frequently clutter. This does not denote general failure in the IIR Doppler filtering of the signal processors.The reason is that the mean profiles were calculated from linearly averaged Z, not dBZ. Only a few bins containing strong peaks of remaining ground clutter will make the distribution of Z so skew that average Z deviates 10-30 dBZ from the mode of Z. In the quality control of raw profiles we limited the vertical reflectivity gradient in the lowest 500 m not to be steeper than -1 dBZ/200m. In cases of fake bright bands, i.e. peaks of reflectivity at heights not matching to the bright band height from the high resolution NWP model HIRLAM, we performed vertical smoothing.

In Table 2 elevated precipitation denotes usually layers of Altostratus or Cirrostratus "cloud". Large areas of widespread frontal precipitation can be overhanging i.e. hydrometeors will not reach the ground although precipitation is present in the lowest elevation PPI at longer ranges. Such occasions can be fatal for any correction based on an observed VPR close to a radar as the correction factor tends to be much larger than 1 at longer ranges whereas the proper correction factor should be 0, i.e. elimination of overhanging precipitation. In March 2001 the diagnosis of such regions is not yet ready. It is aimed to be based on the measured time series of instantaneous VPRs close to each radar (range 40 km), on the shape of the reflectivity pattern on PPI, on the vertical distribution of the precipitable water in the HIRLAM model and on the comparison of reflectivity patterns in the overlapping areas of neighbouring radars. Fig. 2 exhibits an example of an approaching frontal snowfall area. In that case it took almost 3 hours above the radar until the precipitation of the frontal lid reached the ground level. With a typical speed of a precipitating system, 10 m/s, the width of the overhanging zone will be more than 100 km. Overhanging precipitation may form 1-3 layers and it expands both upwards and downwards when the system approaches the radar.

2. METHODS OF ESTIMATING VERTICAL PROFILES OF REFLECTIVITY BETWEEN RADAR SITES

When we can remove areas of overhanging recipitation, the correction of the remaining precipitation due to the VPR will be easier. Still the algorithm should be capable of avoiding severely biased precipitation estimates in any possible time-space distribution of VPR. In cases of severe beam overshooting (VPR correction exceeds e.g. 20 dBZ) we will draw a warning ring at the respective range from the radar, to diagnose the limit of detection for precipitation exhibiting the same vertical structure as is observed close to the radar. The good point in estimating the VPR in Finland is that the country is flat compared e.g. to Switzerland (see Joss and Germann, 2000).

The profile itself and thus, the correction factor due to VPR, is estimated at each composite image pixel as a weighted average of the following components, which are in the order of preference:

1. Time averages of the individual VPRs derived from the 3D volume scans close to each radar at 15 minute time intervals. Each individual profile must be diagnosed as precipitation reaching the ground. Time average gets more weight the more widespread and the longer lasting precipitation system is. Time averaged profiles from each radar will be interpolated in space between radars so that seams will not appear along the bordering lines of individual radars in a composite.

2. The shape of the radar derived, non-corrected accumulated precipitation (period 1-24 h) as a function of range. It is assumed that in a idespread precipitation the observed accumulation should not decrease strongly as a function of range. The weight of this correction estimate depends on the azimuthal homogeneity of the precipitation field. A cross reference is performed so that correction 1 should not deviate much from the observed radial structure of the measured accumulated precipitation.

3. The hourly 2D field of VPR is estimated from the vertical distribution of precipitable water in the NWP model HIRLAM. Six hourly forecasts are used as the best estimate "analysis" of actual precipitation. Due to difficulties in forecasting correctly the location of precipitating systems, especially in convective cases, we will not apply strictly the single grid point profiles but rather the average shape of model VPR in wider areas. Even if the model rain is at wrong place, the model probably can well estimate typical height distribution of precipitation. It can also diagnose cases in which overhanging precipitation occurs. Fig. 3 shows the first example of a VPR from the HIRLAM model and the respective VPR from a radar.

15 July, 2000

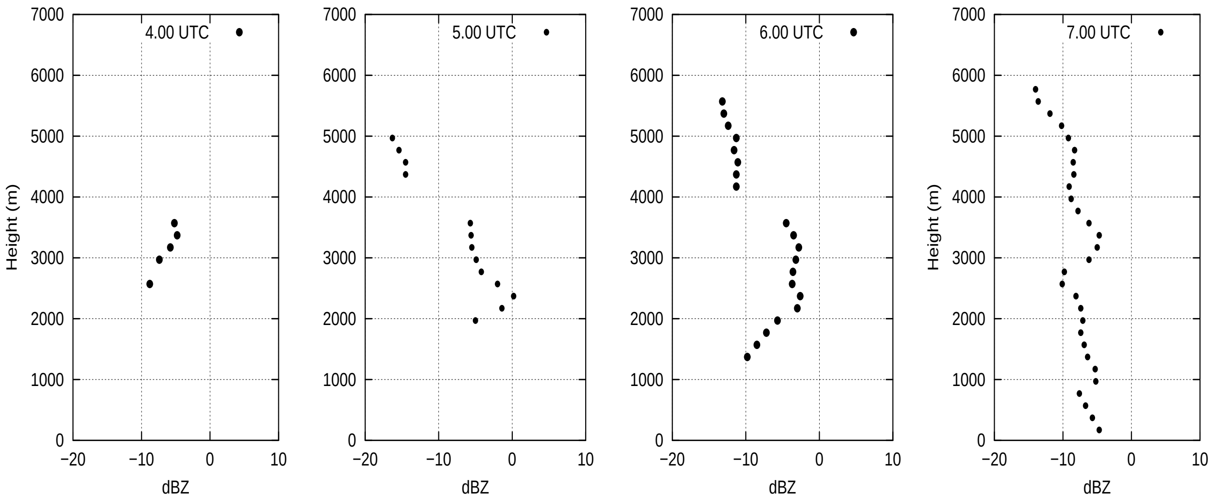

Figure 2: A typical time series of the VPR of an approaching frontal snowfall system.

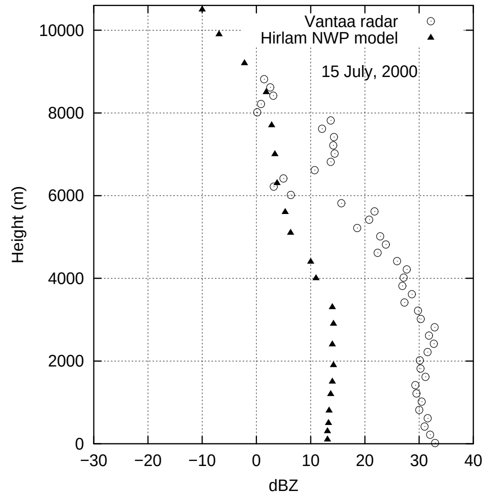

Figure 3: Simultaneous vertical reflectivity profiles on 15 July, 2000, obtained from a radar and from the precipitation intensity profile in the NWP model HIRLAM, at the grid point closest to the radar.

The case consisted of thunderstorms, thus the radar profile is an average of 3 VPRs of rain (12:15-12:45 UTC) closest to the model output time 12 UTC. In spite that the respective intensities deviate quite much, the height and shape of both profiles is surprisingly similar. In the VPR correction the actual values are less important than the shape of the profile compared to the ground level intensity.

4. Climatologically shaped VPR adjusted by the actual height of the melting level, obtained from the 3D temperature distribution of the HIRLAM model.

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