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Identification and elimination of overhanging precipitation

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1 Introduction

Precipitation in cold climates, like that in Finland, is quite shallow, in snowfall only 2–5 km high. In such cases the vertical profile of reflectivity is the dominating factor in the accuracy of measurements of precipitation at ranges of 50–250 km from a radar. The large bias of 2–20 dB, observed in gauge-radar comparisons, is fully originated from the sampling difference between the actual reflectivity (precipitation) at the ground level and in the contribution volume aloft (Koistinen et al., 2003a). We have implemented a real time VPR correction scheme of the measured dBZ to represent reflectivity at ground level (Koistinen et al., 2003b). The correction is calculated to all ranges (0–250 km) in a network of 7 C-band Doppler radars. Vertical profiles are estimated from the measured VPRs close to the radars (0–40 km) and from climatological VPRs adjusted with the height of the freezing level, obtained from NWP model fields.

Layers of overhanging precipitation (OP), not reaching the ground, or areas of significant evaporation are problematic for any correction based on an observed VPR close to a radar. Typically positive VPR corrections at long ranges can make surface precipitation estimate less representative at the ground level in overhanging precipitation areas than without correction at all. Prior to any VPR correction overhanging precipitation areas should be totally eliminated if we want to get the best possible surface precipitation intensity estimate. Above the radars areas of overhanging precipitation can be easily indentified with VPRs measured close to radars. In the radar network between radars and at long ranges from a single radar the situation is more complicated.

2 Methods and results

At the Finnish Meteorological Institute vertical reflectivity profiles (VPR) have been measured and diagnosed regularly now for four years. Profiles are derived from the 3D polar volumes inside the range of 40 km from each of the seven Doppler radars. Profiles are measured in 200 m thick layers at intervals of 15 min. Main use of VPR is the calculation of vertical reflectivity profile correction but at the same time calculations also produce useful statistics about VPR characteristics. An automatic classification algorithm for the VPRs has been created.In a two and a half year long period of radar data (556 471 VPRs) 49% of VPRs represented clear air echo, 40% precipitation and 11% was overhanging precipitation. Additionally 4% of the cases classified as precipitation contained a second, overhanging layer of precipitation above the first one reaching the ground.

Wide areas of overhanging precipitation are typical ahead of a warm or occluded fronts. Diagnosis of OP can be done from the volumetric radar data applying precipitation base height field from the radar network. However, the product is useful only up to the range where the lowest elevation beam is completely below the precipitation base and thus, a base height can be detected. In some cases the base height can't be diagnosed as clear air echo (insects or birds) or clutter occurs in the lowest elevation angles below the actual precipitation base. In such occasions the reflectivity profile is continuous from the lowest level to precipitation top height and the VPR can be easily misidentified as precipitation. Obviously it is a very demanding task of pattern recognition to interpolate the diagnosed base to areas where the radars can't see a base (where the lowest elevation beam hits the overhanging precipitation). Isotropic interpolation schemes will certainly fail as areas of OP form typically elongated patterns at the leading edge of frontal precipitation.

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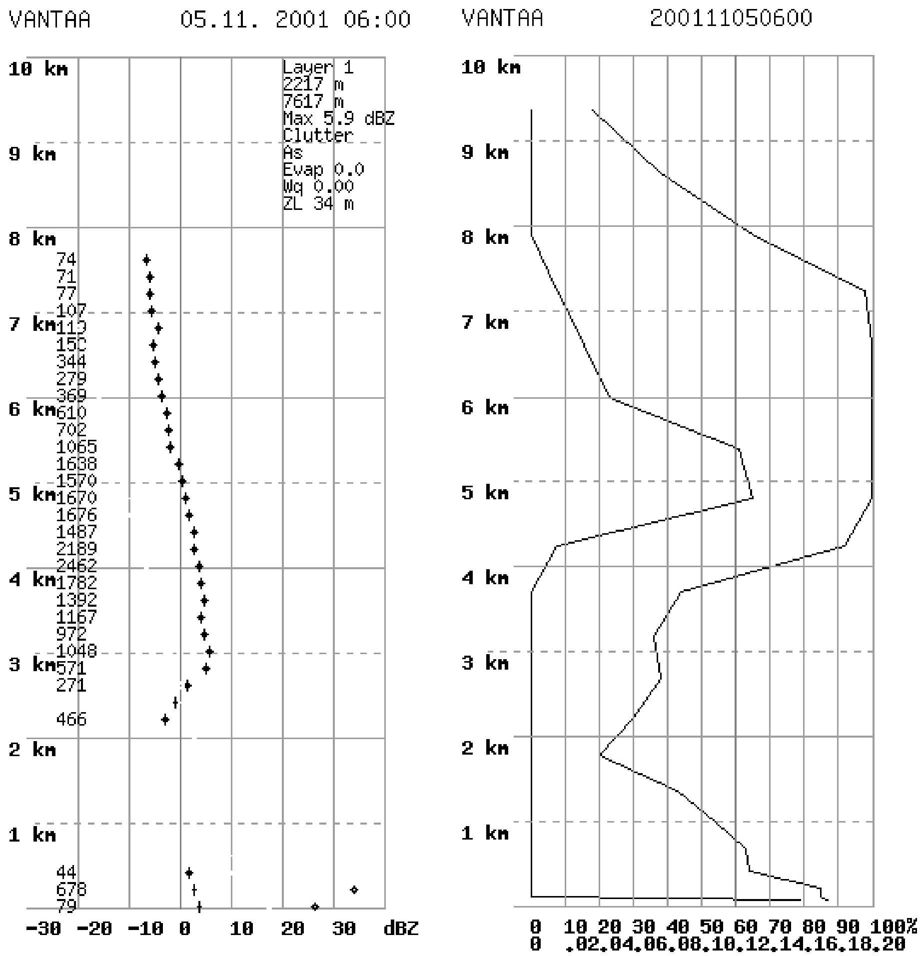

Fig. 1. Left: Vertical profile of reflectivity measured at Vantaa radar on 5 Nov. 2001, 06 UTC. Right: Vertical profile of cloud water content (left curve, lower scale) and relative humidity (right curve, upper scale) from the 6 h operational forecast of the NWP model HIRLAM at the grid point closest to radar Vantaa

An other possible tool for diagnosing OP is the vertical distribution of precipitation obtained from a numerical weather prediction (NWP) model (Michelson, 2003). In the VPR correction scheme (Koistinen and Pohjola, 2003b) we have used temperature from the NWP model HIRLAM for the diagnosis of the 3D hydrometeor water phase applying freezing level height from the model. Mittermeier and Illingworth (2003) have shown excellent agreement between NWP model and actual freezing level heights. Clouds are generated in the model when relative humidity reaches some selected thresholds according to the Sundqvist (1988) scheme. The excessive humidity is then converted to liquid or solid cloud water content (CWC). When the amount of CWC exceeds some parameterized thresholds precipitation is generated. It will immediately fall down to ground level during a single time step. However, the falling precipitation is attached with an evaporation scheme at all model levels. Thus the generation process of large scale overhanging precipitation is present in the HIRLAM model. Unfortunately the 3D distribution of precipitation is not available from the model as it is not a 3D model variable which is saved to files among other model quantities during the forecast calculations. For that reason we have applied the vertical distributions of relative humidity (RH) and CWC at the grid points closest to each radar as a first quess to diagnose the vertical distribution of precipitation. The forecast length applied is 6 hours, which should be enough to avoid spin-up problems of precipitation but short enough to avoid major forecast errors. Figure 1 exhibits an example case of overhanging precipitation. In this example all quantities, RH and CWC from the NWP model as well as VPR from a radar show an elevated layer. However, each quantity diagnoses somewhat different vertical locations for the layer of overhanging precipitation.

In spite of good agreement in individual cases a statistical comparison between the measured VPR and VPRs estimated from the HIRLAM model variables RH and CWC have poor correlation. We have picked up all OP cases from the Finnish radars and from the HIRLAM model gridpoints located closest to each radar covering a period of one year (Table 1). It can be concluded that the 6 hour forecast HIRLAM field of CWC is not efficient in diagnosing OP. As NWP quantities were available only at time intervals of 6 h the result may be

Table 1. Overhanging precipitation profiles (OP) diagnosed at Finnish radars compared to OP diagnosed from the HIRLAM model cloud water content profiles from March 2001 to May 2002. In total 1827 profiles were diagnosed as OP either by radar or by the NWP model.

		HIRLAM	
		OP	No OP
RADAR	OP	244	120
RADAR	No OP	604	859

worse than the actual model performance. As the comparison time was instantaneous any motion phase error of the precipitating weather systems (fronts) will make radar-NWP comparisons worse i.e. a model may build up a pattern of OP but it is not located at the column of reference at the correct time moment. Better results would be expected when the 3D precipitation content can be obtained from the NWP model. An implication is that so far one should be careful when applying NWP model profiles (Michelson et al., 2003) when estimating evaporation and OP at long ranges where radars overshoot regions of strong evaporation below the OP.

3 Conclusions

At present the use of operational very short range NWP model fields (cloud liquid contect, relative humidity) from the HIRLAM model can not be used to diagnose and eliminate overhanging precipitation (OP) from radar measurements at long ranges. Precipitation base height composites, derived from the polar radar data volumes, reveal the occurrance of OP at shorter ranges. They can be used as a diagnostic product to warn that OP is present at least somewhere in the region covered by the radars. A human can try intelligent extrapolation of these regions (e.g. based on the known location of the leading edge of frontal precipitation).

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