CARPE DIEM

Critical **A**ssessment of available **R**adar **P**recipitation **E**stimation techniques and **D**evelopment of **I**nnovative approaches for **E**nvironmental **M**anagement

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Deliverable 7.3

Improvement of radar derived surface precipitation using integrated OP correction from a radar network and from a NWP model

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1. *Introduction*

The surface estimate of precipitation pattern based on radar reflectivity algorithms suffers from variations in both hydrometeors water phase (i.e. the dielectric factor) and their vertical distributions. This is valid especially in cold climates where rain, snow and sleet are always present in the 3D volumetric radar data. This WP concentrates on the reduction of sampling differences between the real surface precipitation and that estimated from the radar sample aloft. Combined correction algorithms which take into account radar data, surface observations and NWP model fields were created and implemented to the operational radar product generation at FMI. These products are applied, among others, by the End Users of FMI, i.e. Kemijoki Oy (for hydrological purposes) and the Finnish Road Authority (for optimizing prevention actions against slippery conditions due to snowfall).

2. *Applied methodologies*

The Work has been organised following this logical steps:

- The impact of attenuation correction considering the actual 3D water phase distribution**.**
- Diagnosis and elimination of long range precipitation errors due to overhanging precipitation not reaching the ground.
- The impact of variations in the vertical profile of reflectivity (VPR).

3. *Scientific achievements*

Layers of overhanging precipitation (OP), not reaching the ground, or areas of significant evaporation are problem 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. Near the radars areas of overhanging precipitation can be easily identified with VPRs measured close to radars and comparing data from several elevation angles. In the radar network between radars and at long ranges from a single radar the situation is more complicated.

Diagnosis of overhanging precipitation can be done close to each radar applying precipitation base height field from the radar network. An example case of overhanging precipitation at the leading edge of a snowfall area is shown in Fig. 1. Only the dark blue area is precipitation reaching the ground or at least the height of the lowest elevation angle. All other colours indicate that the height of the precipitation base is located above ground.

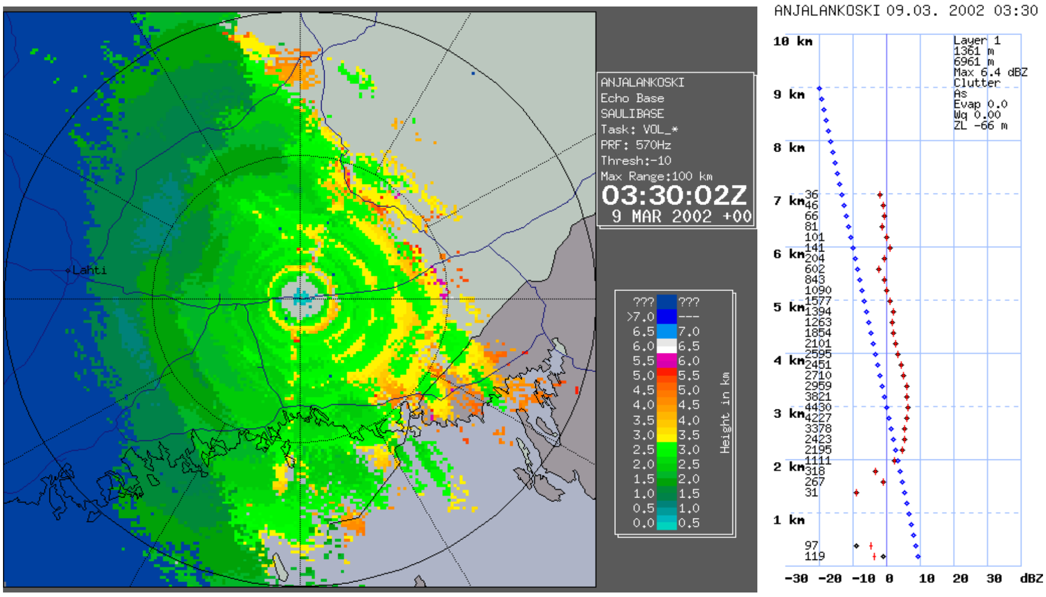

Fig. 1 – An example of the height overhanging precipitation (km) above Anjalankoski radar and classified VPR measured at the same time

Applying composites from each radar diagnosis of overhanging precipitation can be mapped applying base height field composite. In Fig. 2 is shown an example of base height field composite. All blue and green areas indicate that the height of the precipitation base is located above the ground.

Precipitation base height from radars is not applicable in areas where the actual base is below the lowest elevation beam. 3D diagnosis of OP based on NWP model fields is possible tool for diagnosing OP in these areas. Measured overhanging precipitation (OP) VPRs can be compared to HIRLAM model specific cloud water condensate (CWC) profiles. Clouds are generated in the model when relative humidity reaches some selected threshold according to the Sundqvist scheme. The excessive humidity is then converted to liquid or solid specific 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 primitively 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 the reason we have applied the vertical distribution of relative humidity (RH) and CWC at the grid points closest to east radar as the first guess to diagnose the vertical distribution of precipitation. If specific CWC profiles and VPRs would be strongly correlated, we could use HIRLAM model data to diagnose OP between radar sites.

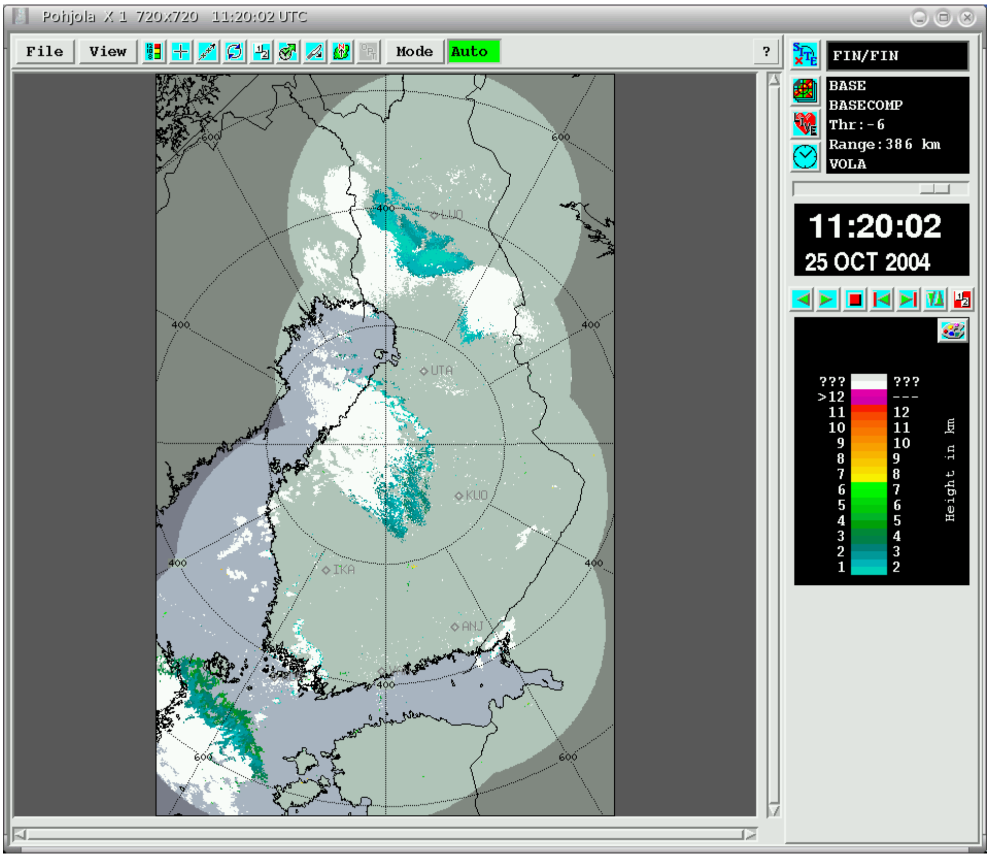

Fig. 2 – An example of precipitation base height field composite in Finnish radar network. All blue and green areas indicate that the height of the precipitation base is located above the ground

In Fig. 3 is an example of specific CWC and RH profiles from HIRLAM model and the measured VPR above Vantaa radar. All quantities, RH and CWC from the HIRLAM model as well as VPR from the radar show an elevated moist or precipitating layer. However, each quantity diagnoses somewhat different vertical locations for the layer of overhanging precipitation. Anyway the figure suggest that NWP models offer potential to diagnose OP.

In Tab. 1 is shown diagnosed OP VPRs from March 2001 to May 2001 at the seven Finnish radars compared to the respective OP diagnosis obtained from the 6 hour forecasts of NWP model HIRLAM. In spite of good agreement in some individual cases a statistical comparison between the measured VPRs and VPRs estimated from the HIRLAM model variables RH and CWC have poor correlation. In 1103 cases out of 1827 cases model and radar have diagnosed OP. In 604 cases there exists OP according to the specific cloud condensate profile out according to VPRs in the same case, OP does not exists. In 120 cases diagnostics are vice versa.

Table 1 – Overhanging precipitation profiles (OP) diagnosed at Finnish radars compared to OP diagnosed from the HIRLAM 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.

<table>
<tr><td colspan="4">HIRLAM model</td></tr>
<tr><td rowspan="3">Radar</td><td></td><td>OP</td><td>No OP</td></tr>
<tr><td>OP</td><td>244</td><td>120</td></tr>
<tr><td>No OP</td><td>604</td><td>859</td></tr>
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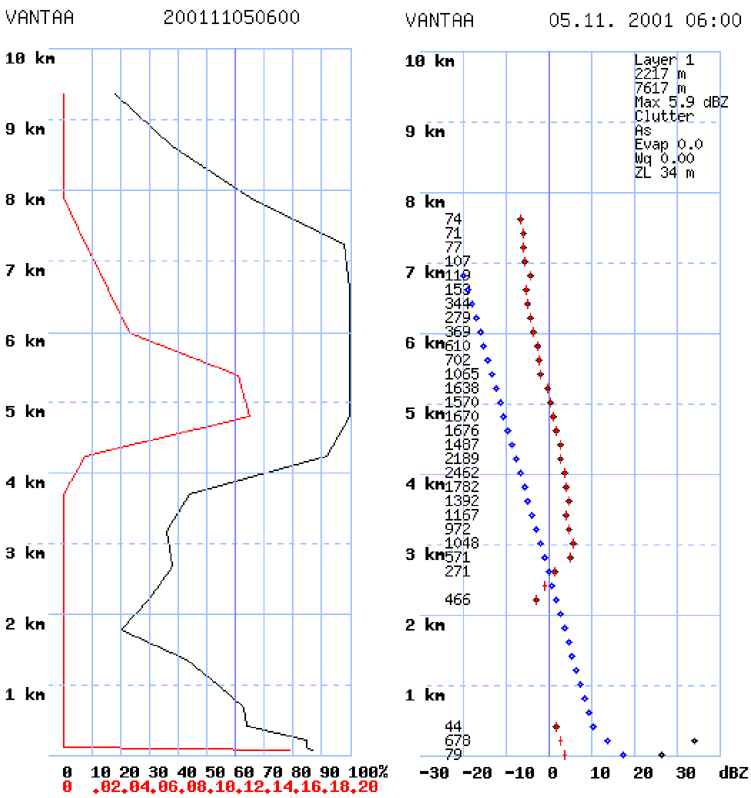

Fig. 3 – Measured VPR (right panel), specific cloud condensate (red) and relative humidity (black) (left panel) from the NWP model HIRLAM 6 hour forecast in an overhanging precipitation case.

Improvement of radar derived surface precipitation using attenuation correction applying 3D water fraction from a NWP model. The methodology is that with the known freezing level height at each radar obtained from NWP and VPR we can calculate attenuation separately in each water phase layer. We have searched equations for attenuation in each water phase. In rain and the snow specific attenuation is well known, but for melting snow (bright band) a general algorithm could not be found. We use in the melting layer attenuation correction for rain (I. Zawadzki, pers. comm.).

Precipitation is liquid: $k(\mathrm{dB/km})=1.12*10^{-4}\, Z_e^{0.62}$

Precipitation is snow: $k(\mathrm{dB/km})=1.1*10^{-7}\, Z_e + 2.1*10^{-5}\, Z_e^{0,5}$

Bright band: $k(\mathrm{dB/km})=1.12*10^{-4}\, Z_e^{0.62}$

In Fig. 4 is shown a severe attenuation case in summer time. In the left strong mesoscale convective complex (MSC) is approaching Finland from south. South of the strong convective cells containing large hails radar beam is strongly attenuated. North of MSC located Anjalankoski radar can not see barely anything behind MSC. Vantaa radar located west of MSC measures correct without attenuation also south of convective cells and bad seam can be seen in the radar composite in that area. In the right panel MSC is already north of Anjalankoski radar and radar beam is not anymore attenuated south of MSC.

In Fig. 5 is shown the lowest PPI´s B-scan of Anjalankoski radar in the same situation as in Fig. 3. In the left panel is shown B-scan before and in the right panel after the attenuation correction. This attenuation correction method does not fully recover observed minima. Reason for poor correction can be significant radome attenuation and/or large hails that this method does not take into account.

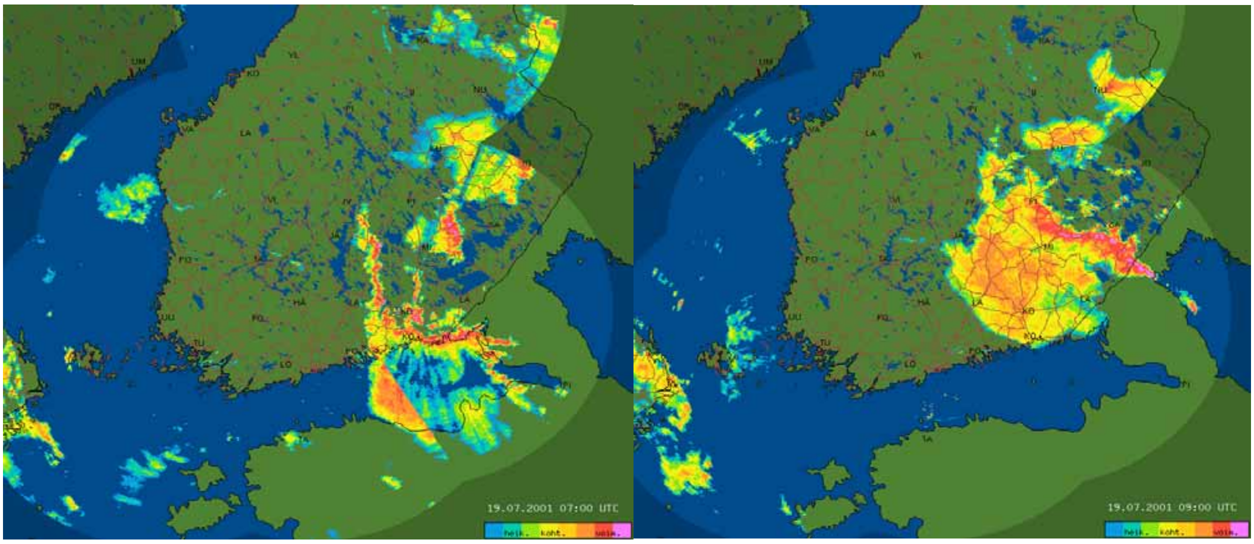

Fig. 4 – Severe attenuation case in summer time MSC. In the left panel can be seen strong attenuation south of strong convective cells causing seam in radar composite in that area. In the left panel MSC is north of Anjalankoski radar and radar beam is not anymore attenuated in that area.

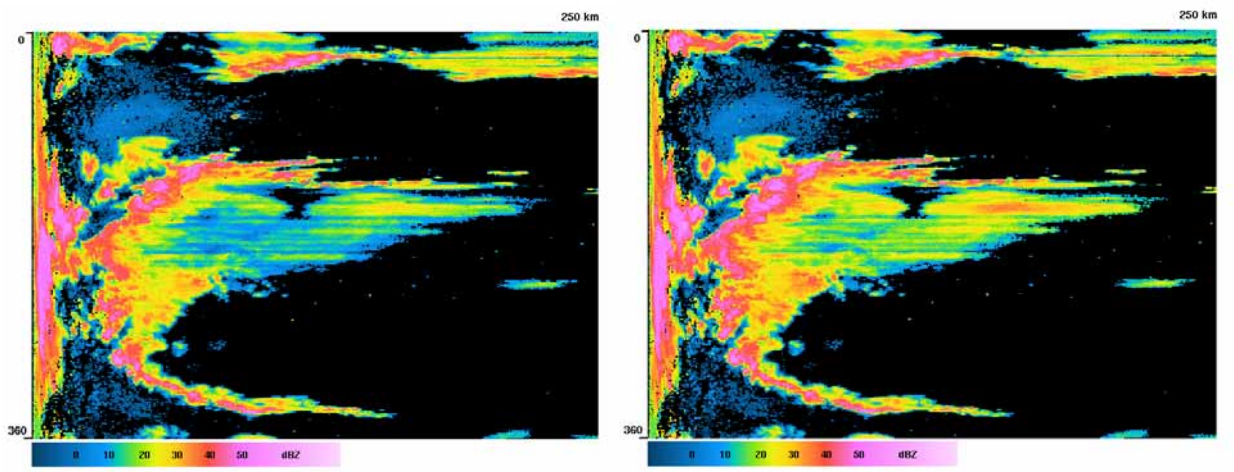

Fig. 5 – B-scan image of the lowest PPI at Anjalankoski radar in the situation of Fig. 3. In the left panel situation before and in the right panel after the correction.

4. Main deliverables

As the magnitude of the VPR corrections in any cold climate or in the winter time cold climates are huge (5 - 30 dB) at longer operational measurement ranges, the impact of the correction is significant for any customer applying quantitative or even semi-quantitative radar based precipitation measurements (both dBZ and accumulated ones). The operational implementation of the VPR correction scheme results to much better performance of radar data at longer ranges and thus extends the quantitatively good radar coverage significantly. Such improvement can directly affect on the reliability and accuracy of End User operations. Less dense C-band radar networks can also save investment costs.

The work performed proves nicely that the bias in radar-based surface estimates of precipitation due to VPR at longer ranges is much larger than any other error in a well calibrated system. Especially in a cold climate a VPR correction at longer ranges is necessary in all QPE.

Any hydrological application aimed e.g. for flood prevention should always ensure that at longer ranges the VPR correction should be performed. Otherwise a significant underestimation of the river flow can follow. The existing version of the VPR classification and correction scheme developed in CARPE DIEM is already an outstanding deliverable, both scientifically and for any operational radar system, which was also supported by the End Users of FMI at the National End User Meeting in February 2003.

Acronyms and abbreviations

Acronym	Explanation
CWC	Cloud Water Content
FMI	Finnish Meteorological Institute
HIRLAM	HIgh Resolution Limited Area Model
MSC	Mesoscale Convective complex
NWP	Numerical Weather Prediction
OP	Overhanging Precipitation
PPI	Plan Position Indicator
QPE	Quantitative Precipitation Estimation
RH	Relative Humidity
VPR	Vertical Reflectivity Profile
WMO	World Meteorological Organization