Radar beam overshooting and reduced precipitation detectability in Sweden

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1. Why overshooting matters

Weather radar beams rise with distance because of antenna elevation angle and Earth curvature. They may therefore partially or completely overshoot shallow precipitation, reducing effective range for quantitative precipitation estimation (QPE).

2. Probability of overshooting (POO)

A Finnish Meteorological Institute method implemented in the BALTRAD toolbox [1] that uses reflectivity volume data to estimate the probability that the radar beam passes above a representative precipitation echo-top height per along each radial (**Fig. 1**).

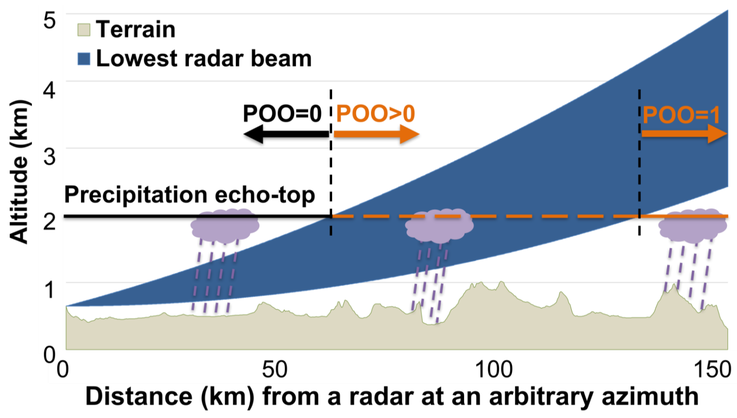


Fig. 1: *Illustration of probability of overshooting (POO).*

3. SMHI radar network

SMHI operates 12 C-band weather radars across Sweden (**Fig. 2**). Of 10 operational elevation angles, the lowest is 0.5°, with a nominal 240-km range. Depending on echo-top height, high POO can occur at varying distances from the radar.

4. Data

Z: 5-min 2 × 2 km reflectivity from the single-radar PCAPPI product, primarily from 0.5° elevation, quality-controlled (QC) for anomalies, beam blockage, and malfunctioning scans.

POO: daily mean 2 × 2 km POO, derived from 5-min QC reflectivity volume data, analysed in seven classes: 0, 0–0.1, 0.1–0.25, 0.25–0.5, 0.5–0.75, 0.75–0.9, and 0.9–1.

QPE: daily 2 × 2 km precipitation, aggregated from 5-min Marshall–Palmer $R = (Z/200)^{1/1.6}$.

Reference: daily 4 × 4 km PTHBV precipitation [2], interpolated to 2 × 2 km grid.

Study period: 2022–2023.

5. Detectability metrics

The metrics described in **Table 1** were used to evaluate precipitation detectability.

Table 1*: Detectability metrics used to compare daily precipitation data from radar and PTHBV.*

Metric	Description	Best
POD	**Probability of Detection:** Fraction of reference precipitation detected by radar	1
GSS	**Gilbert Skill Score:** A score accounting for detections expected by chance	1

6. Daily QPE and POO maps

Daily POO fields correspond more closely to the areal extent of daily QPE during colder seasons than in summer, due to lower sub-daily variability in the echo-top. Radar estimates are largely missing beyond POO contours of 0.25–0.5, indicating a substantially reduced effective QPE range (see **Fig. 3**).

7. Detectability by POO and distance

As shown in **Fig. 4**, across radars and metrics, detectability generally decreases with increasing POO and distance from the radar.

Deterioration with POO is evident within individual distance classes, especially at POO > 0.1, while distance-related differences within a POO class may reflect other quality issues and differences in sample size or distribution.

The magnitude of deterioration varies substantially among radars and seasons, with generally poorer detectability in winter, especially for northern radars. Higher detectability at elevated POO in summer may be related to deeper convective precipitation events, whereas winter precipitation is typically shallower and more stratiform.

8. Conclusions

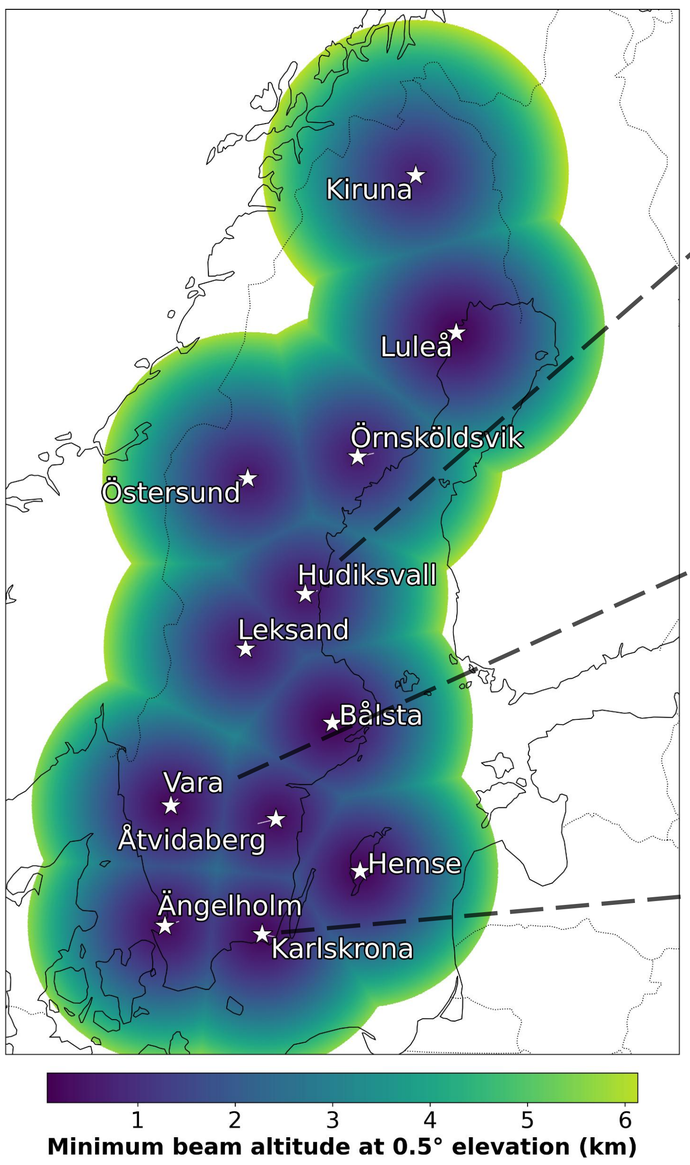
Overshooting can substantially reduce effective radar QPE range, particularly during colder seasons, and POO provides a useful indicator of reduced precipitation detectability.

Detectability generally decreases with increasing POO and radar distance, with varying magnitude among radars and seasons. High POO thus indicates increased risk of precipitation non-detection.

9. Outlook

POO can serve as a quality index in quality-based radar compositing (see poster #204).

Future work can evaluate POO with sub-daily reference precipitation data and, where available, independent echo-top observations.



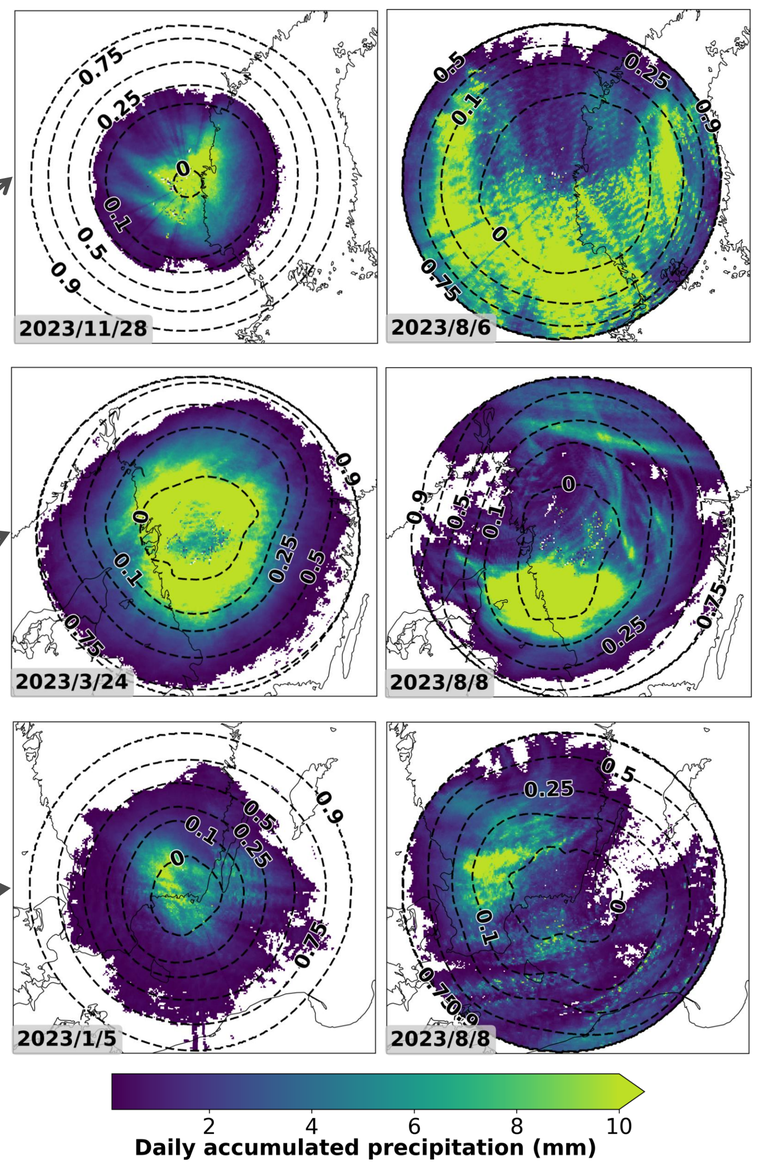


Fig. 2: *SMHI radar network and minimum beam altitude assuming standard propagation and no blockage.*

Fig. 3: *Examples of daily QPE (≥0.1 mm) and POO contours during colder season (left) and summer (right).*

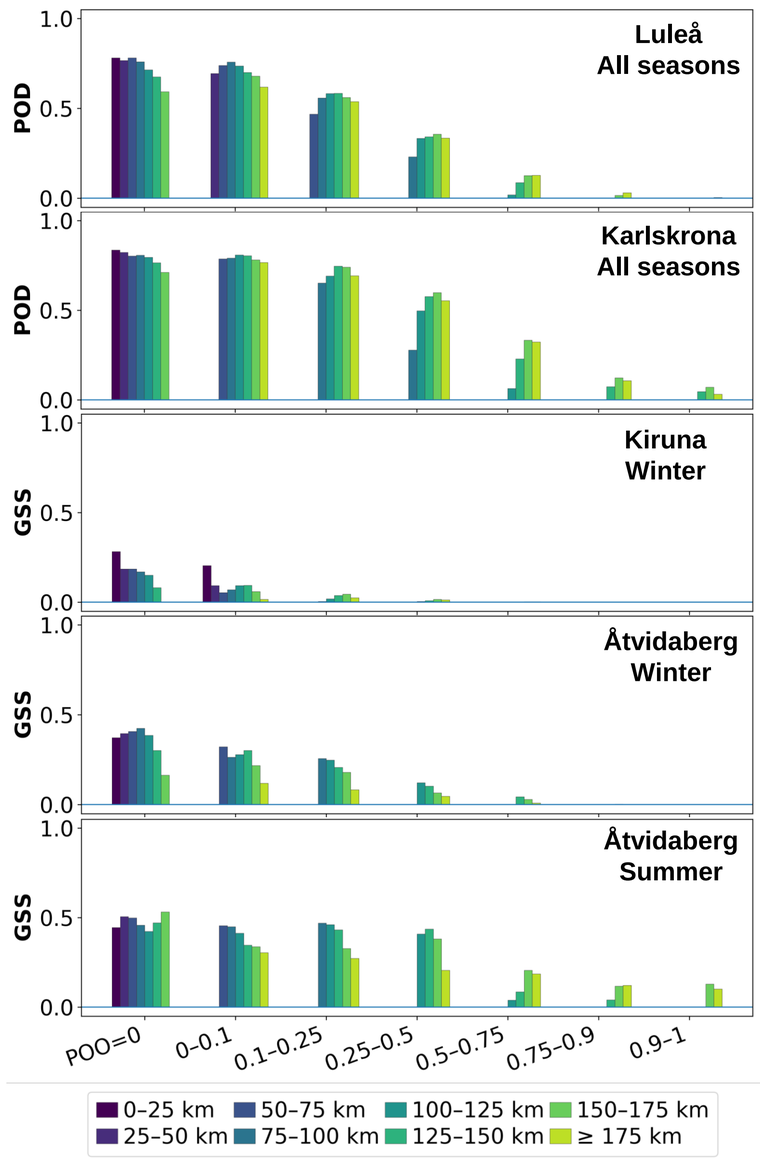


Fig. 4: *Precipitation detectability metrics within POO and distance classes for different radars and seasons.*

References

(1) Michelson, D, et al. 2018 BALTRAD Advanced Weather Radar Networking. Journal of Open Research Software, 6: 12. DOI: https://doi.org/10.5334/jors.193

(2) PTHBV. Griddled daily values of temperature and precipitation over Sweden since 1961. http://data.europa.eu/88u/dataset/d8ec2980-752c-11ed-a51b-432755aaeed3

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