Recent Antenna Calibration Developments at IFE

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Introduction

Phase Center Corrections (PCC) mandatory for precise and accurate GNSS-based positioning

- Institut für Erdmessung (IfE) estimates PCC in the field by use of a robot and real GNSS signals
- Estimation of multi-frequency and multi-GNSS PCC including all signals [1]

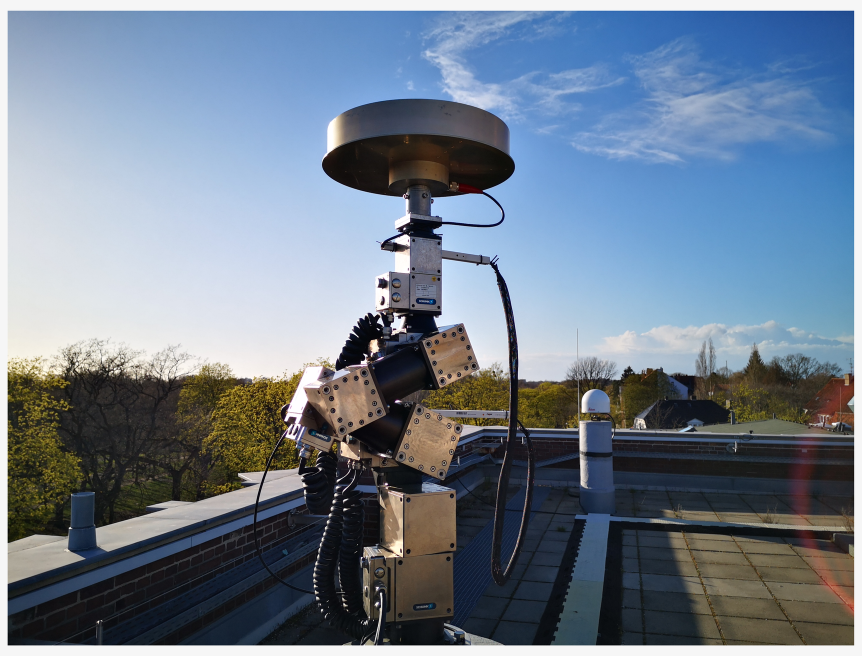

Figure 1: Robot used at IfE to calibrate antennas.

Research Activities

- Estimation of Codephase Center Corrections (CPC) [2]
- Application of special calibration settings & different processing strategies [3]
- Influence of receivers on resulting PCC [4]
- Analysing environmental effects (DFG project MAESTRO, P1: 019)

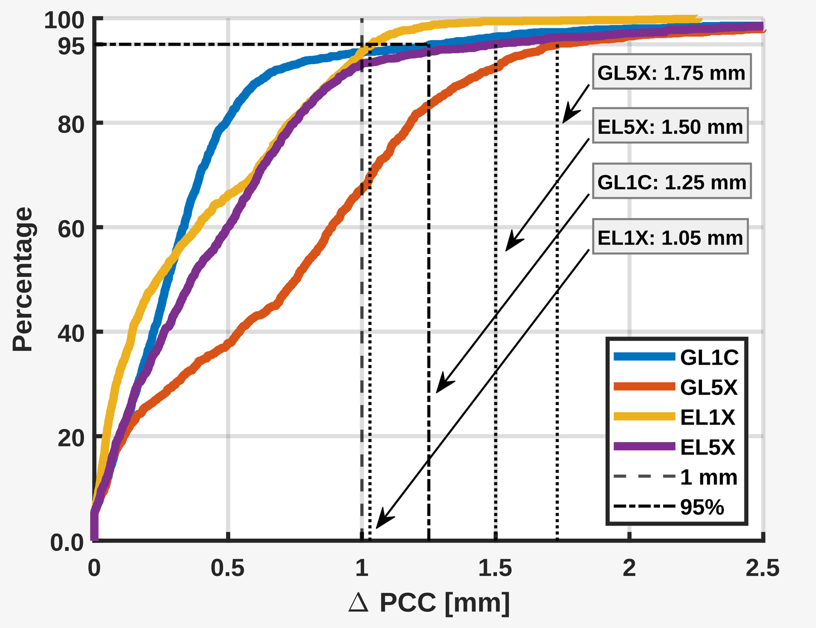

Figure 2: ΔPCC obtained by different calibrations of the same antenna (LEIAR20 LEIM).

Parametrization of Phase Center Corrections

- Usually by Spherical Harmonics (SH) up to degree and order = 12
- Drawback: SH defined for a sphere, PCC estimated and provided for the upper hemisphere of Antenna under Test (AUT)
- AUT tilted by robot → observations present at lower hemisphere
- Due to technical restrictions for maximum tilting angle & cut-off angles: ≈ 85% of observations lie on upper hemisphere resulting in unstable normal equation system ($cond(N) \approx 10^{10}$) → constraints needed, but symmetry assumptions questionable

Use of Hemispherical Harmonics

- Based on [5], associated Legendre polynomials are shifted to interval of existing zenith angles z on antenna hemisphere → $cond(N) < 10^2$ without addtional constraints

Formal Errors of Gridded PCC

- Formal errors of gridded PCC $\sigma_{PCC} < 0.35$ mm (s_0^2 set to variance of input observations, i.e. dSD)
- σ_{PCC} depends mainly on the sampling of antenna hemisphere during calibration process: smallest at mid-zenith angles (most observations) and increasing with higher zenith angles

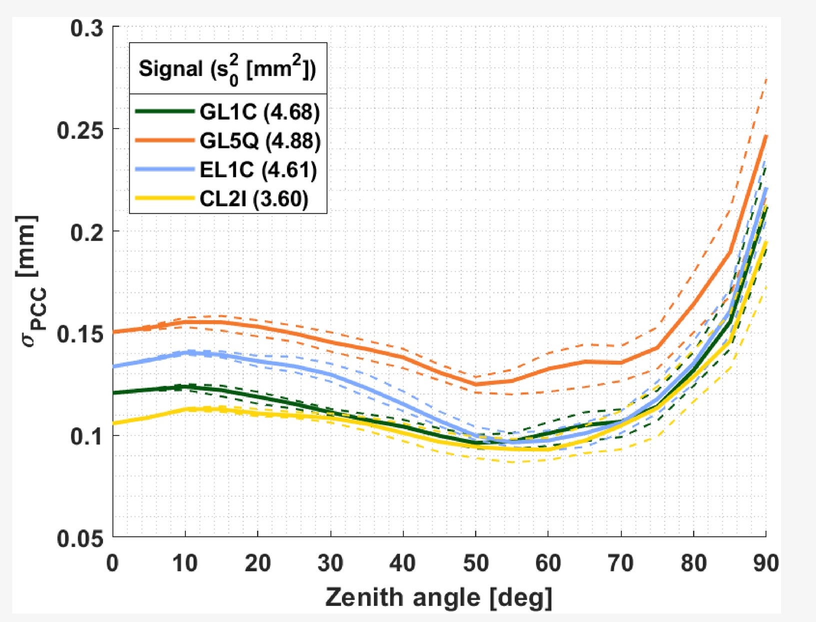

Figure 3: Formal errors σ_{PCC} of one typical calibration set (LEIAR25.R3 NONE).

Comparison Metrics on Pattern Level

- Scalar measures proposed in [6] allow analysing & clustering of PCC from different calibrations (ΔPCC) → Assessing how well calibrations match
- Usually, constant parts in PCC can not be estimated → scalar measures should be independent of constant parts, which is the case for std(ΔPCC) but not for the maximum value

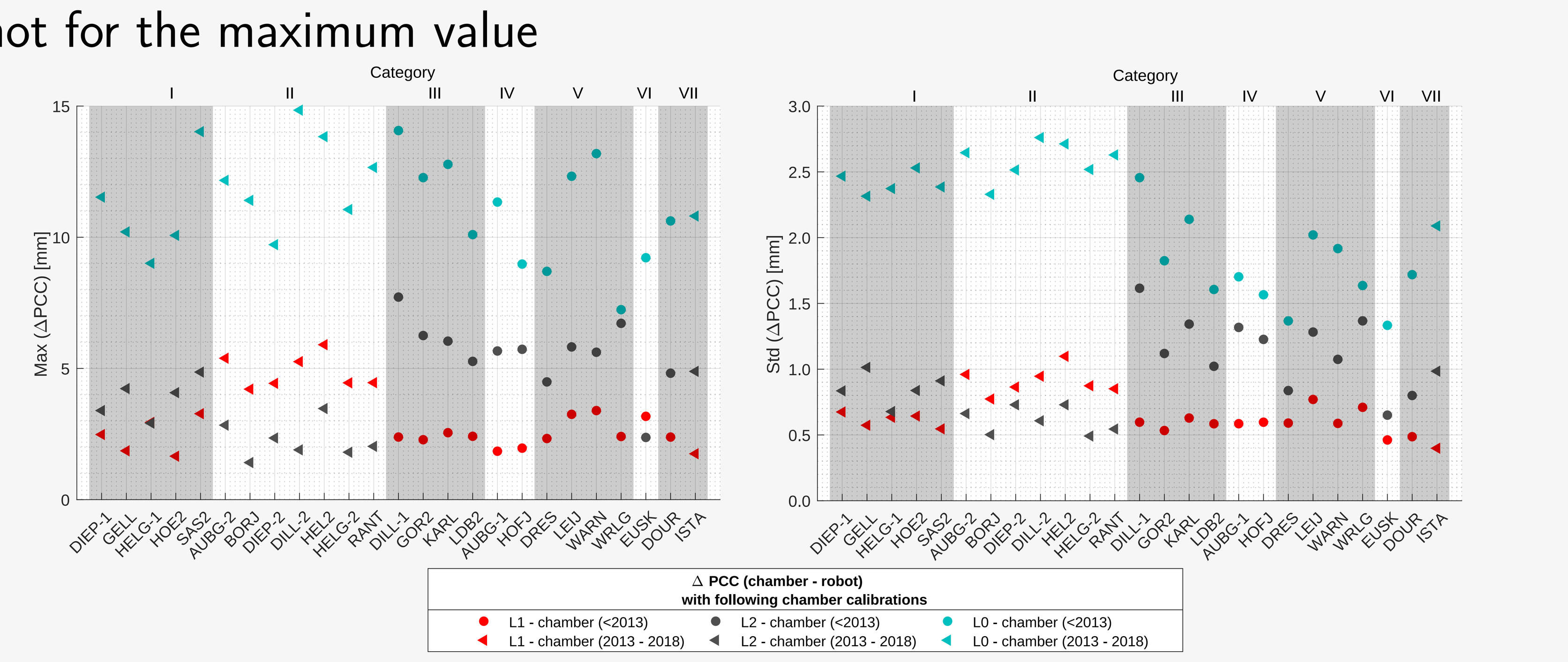

Figure 4: Scalar measures for ΔPCC of method *field robot* and *anechoic chamber* for individual antennas on EPN network sites.

Impact on Geodetic Parameters

- In-house standardized simulation tool allows to assess the impact on geodetic parameters with changing processing parameters
  - Input PCC, timespan, local position
  - multi-GNSS frequencies, linear combinations, sampling rates
  - elevation cut-off angle, observation weighting scheme
- Comparison of simulation with PPP results based on real data: Δ < 0.5 mm

Findings: Developed simulation tool is powerful to analyse impact of ΔPCC on geodetic parameters

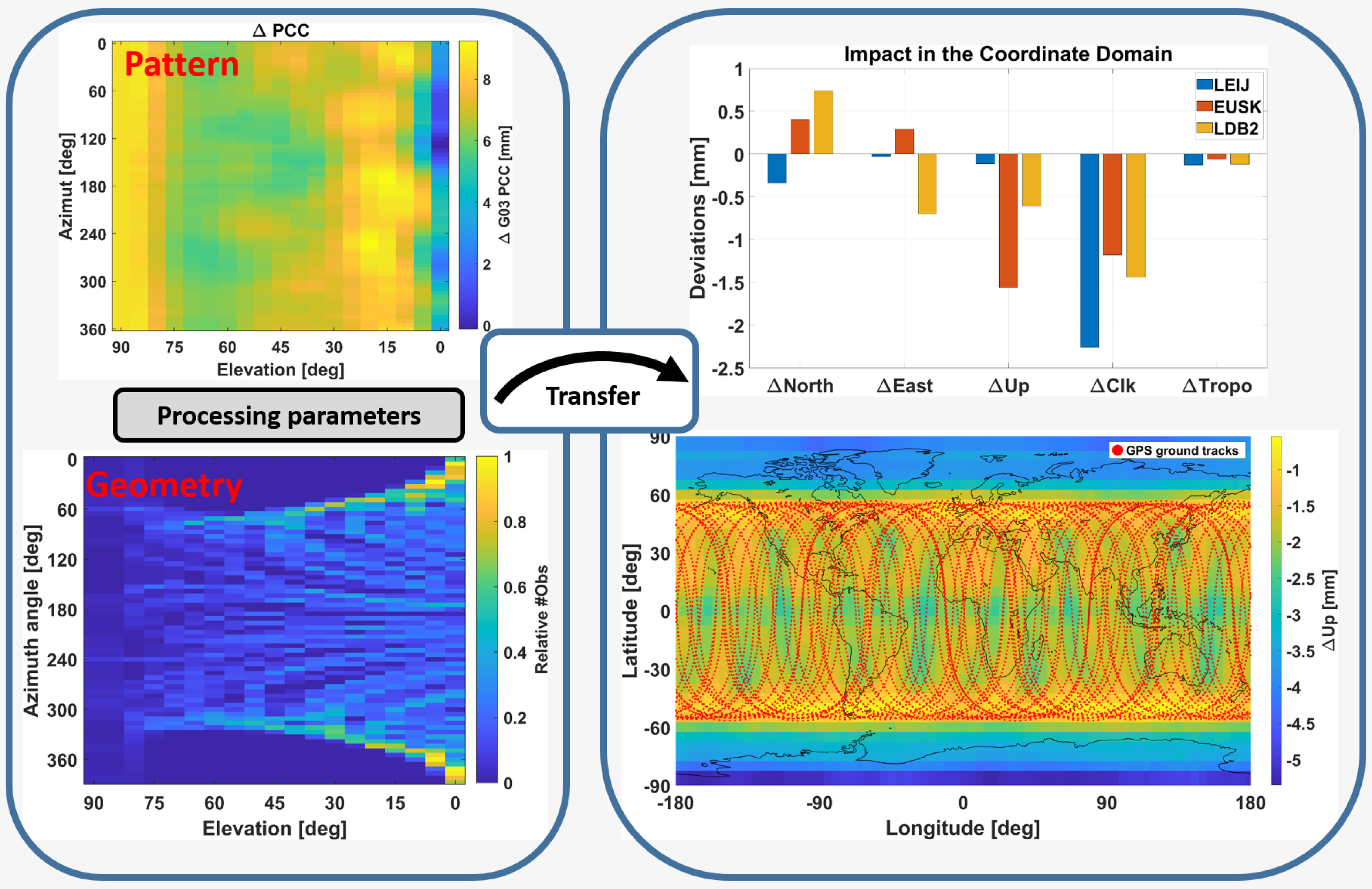

Figure 5: In-house standardized simulation environment to assess impact of ΔPCC on geodetic parameters [7].

Selection Criteria for new PCC values

- Impact of ΔPCC on topocentric 3D-position should not exceed certain threshold, e.g. 4 mm (expectable accuracy for PPP/DD processing)
- Assessing this impact by computing ΔPCC w.r.t. IGS type mean values
- Formal errors, repeatability of individual calibrations and subdaily variations need to be considered, cf. Fig. 6.

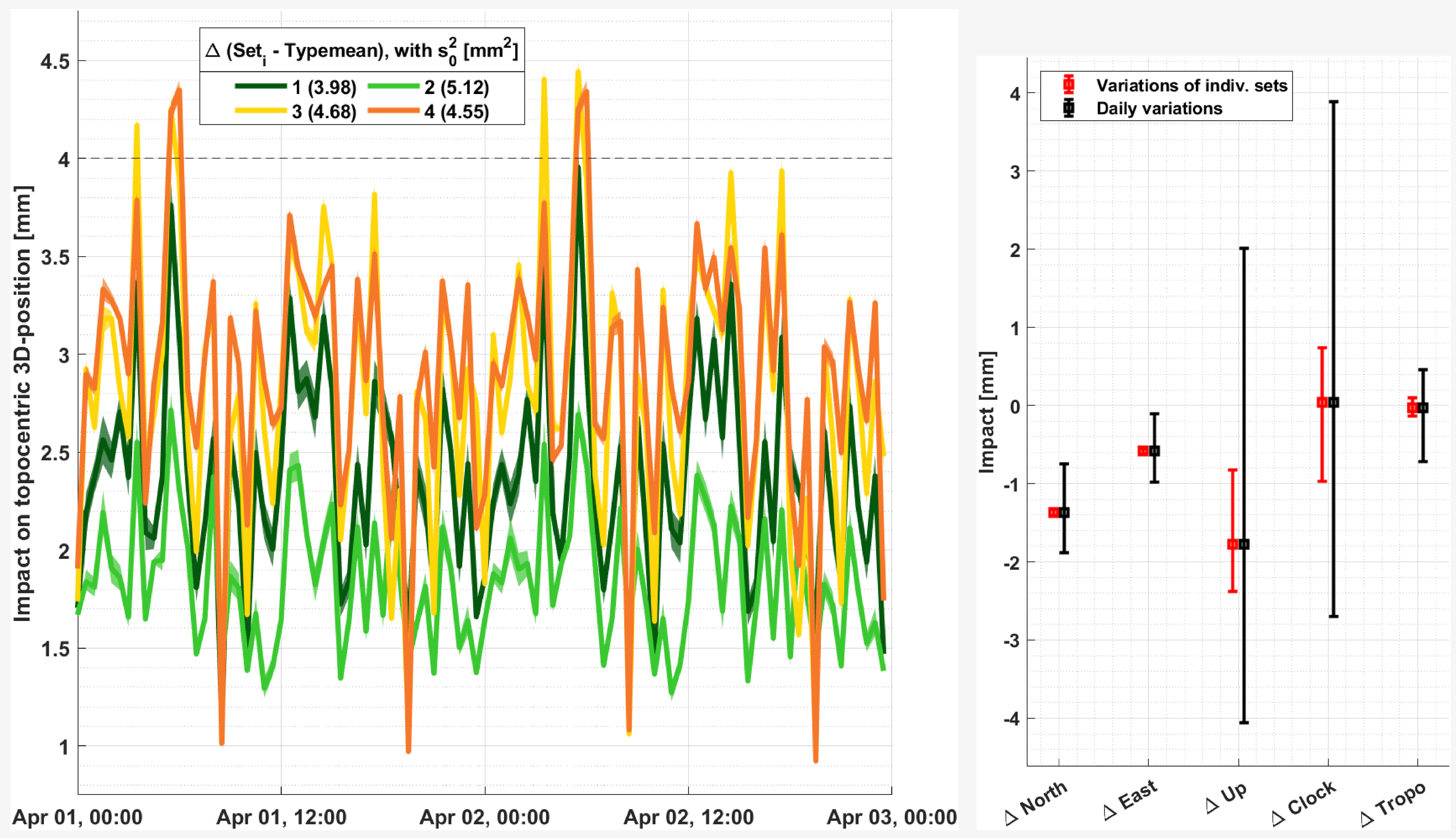

Figure 6: Impact of ΔPCC on topocentric 3D-position for four individual calibrations of NOV703GG.R2 NONE antenna: GPS L1, elevation cut-off angle = 7°, elevation-dependent weighting, location: Hannover (Germany), two days data with $\delta t = 30$ s averaged over an interval of 30 min. Left: impact per epoch, shadowed areas indicate impact of estimated PCC $\pm\sigma_{PCC}$. Right: Differences of IGS to indiv. typemean and corresponding min/max deviation for first 24 h (red), and daily min/max deviations (black).

References

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[2] Y. Breva et al. "Estimation and Validation of Codephase Center Correction Using the Empirical Mode Decomposition". In: *International Association of Geodesy Symposia*. Springer Berlin Heidelberg, 2022, pp. 333–343.

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