

GNSS antenna calibration tables evaluated by means of large volume metrology

Part of EMPIR JRP 18SIB01
Large-scale dimensional measurements for geodesy

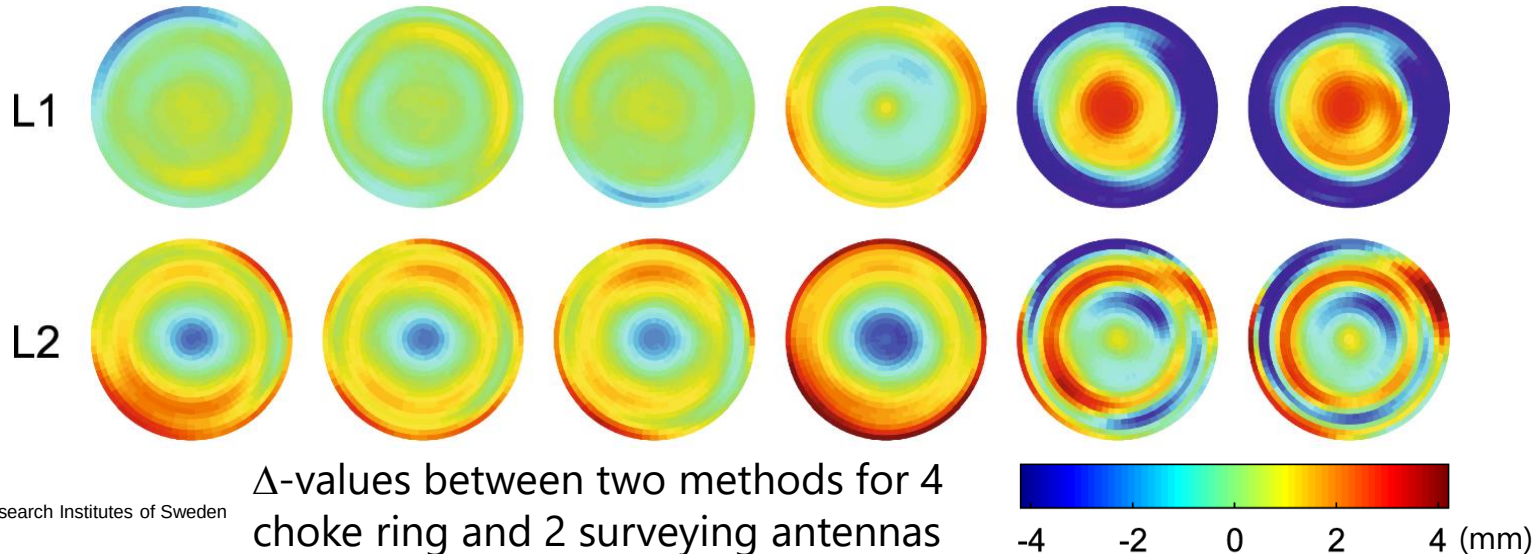


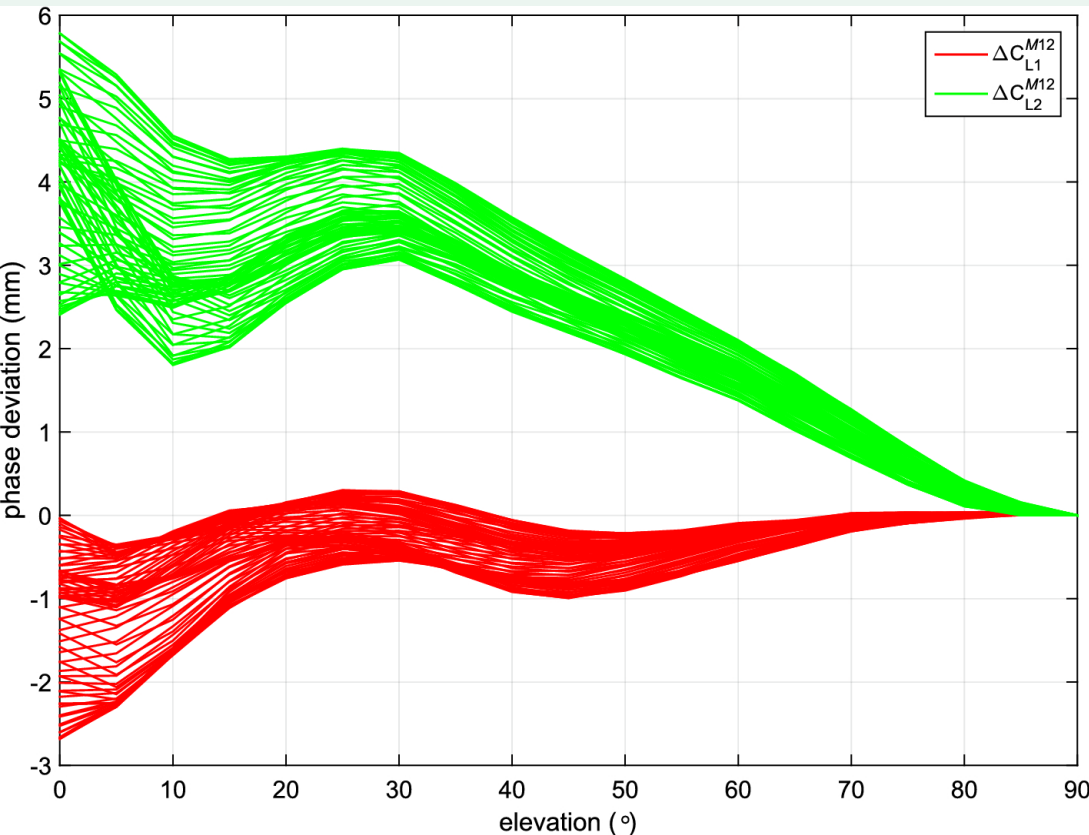
Courtesy: G. Elgered

Difference between calibration methods

GNSS antenna calibration results don't match

- High repeatability within method and antenna type
- Differences between calibration methods systematic and type dependent



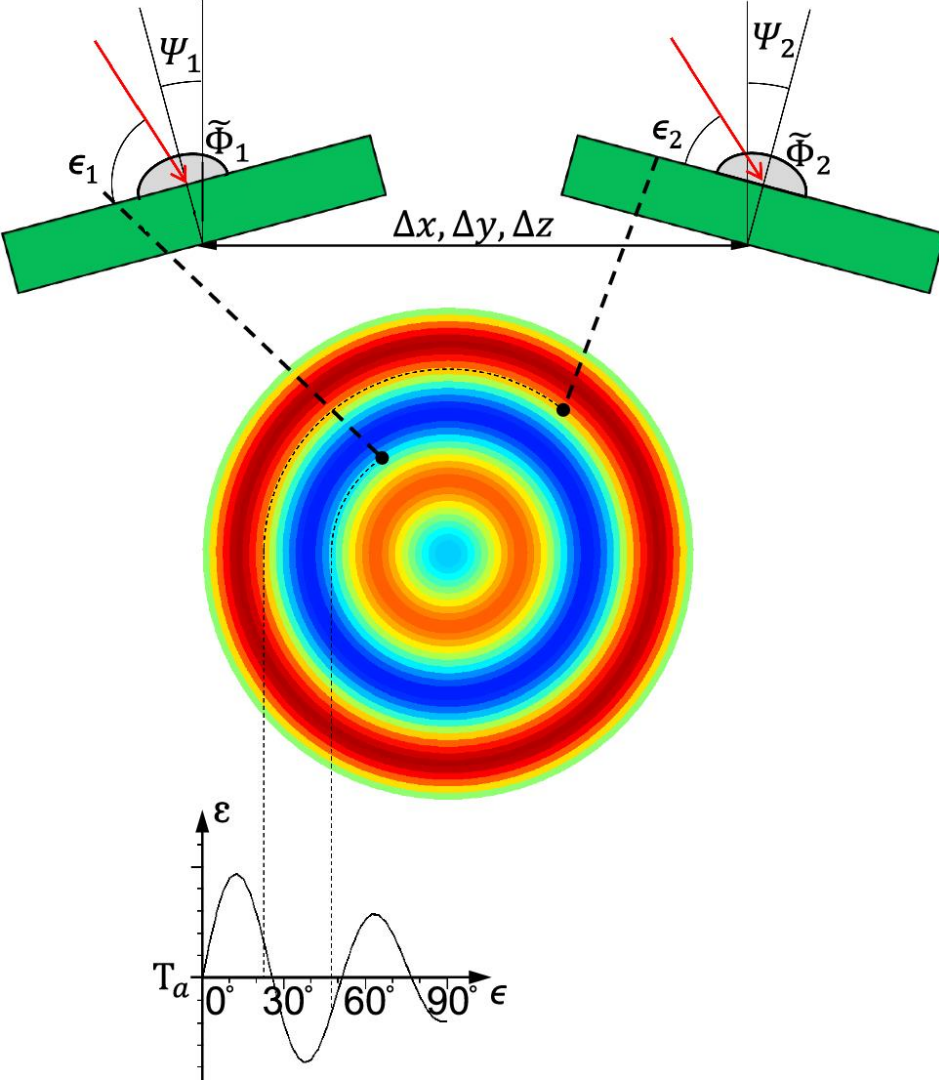


Antenna diagrams

- Calibration table differences $\Delta C_{L1}^{M12}, \Delta C_{L2}^{M12}$ between **M**ethods 1&2 are available for broadcast frequencies L1 and L2, generally $|\Delta C_{L1}| < |\Delta C_{L2}|$
- Calibration differences depend on **e**levation $\Delta C(\alpha, \epsilon) \approx \Delta C(\epsilon)$
- Zenith values are adjusted to zero (GNSS fundamental)
- Phase center is an imaginary non-tangible point. Its **T**rue position – the **C**alibration value minus its **e**rror is

$$T(\epsilon) = C(\epsilon) - \epsilon(\epsilon)$$

Quantifying calibration errors



For identical antennas, an error function appears

- Phase differences between two antennas consist of **Atmospheric** difference, **Geometry** and difference between **True** antenna values (in addition to **time** difference, number of wavelengths and noise)

$$\Delta\Phi_{raw} = \Delta^{Atm} + G + T_2 - T_1 + \tau + N\lambda + \nu$$

- Geometry-related parameters are antenna reference point positions, phase wind-up, doppler effects, and deterministic atmosphere

$$G = f(\Delta x, \Delta y, \Delta z, \tilde{\Phi}_1(\psi_1), \tilde{\Phi}_2(\psi_2), \Delta t\dot{\rho}, \Delta^{Atm}(H, \epsilon))$$

- For identical antennas, the difference in **Calibrated** phase observations equals the difference between the calibration errors as observed at different elevations

$$\begin{aligned}\Delta\Phi_C &= \Delta\Phi_{raw} - (C_2(\epsilon_2) - C_1(\epsilon_1) + G_{\perp} + N) \\ &= \epsilon(\epsilon_2) - \epsilon(\epsilon_1) + \tau + \nu\end{aligned}$$

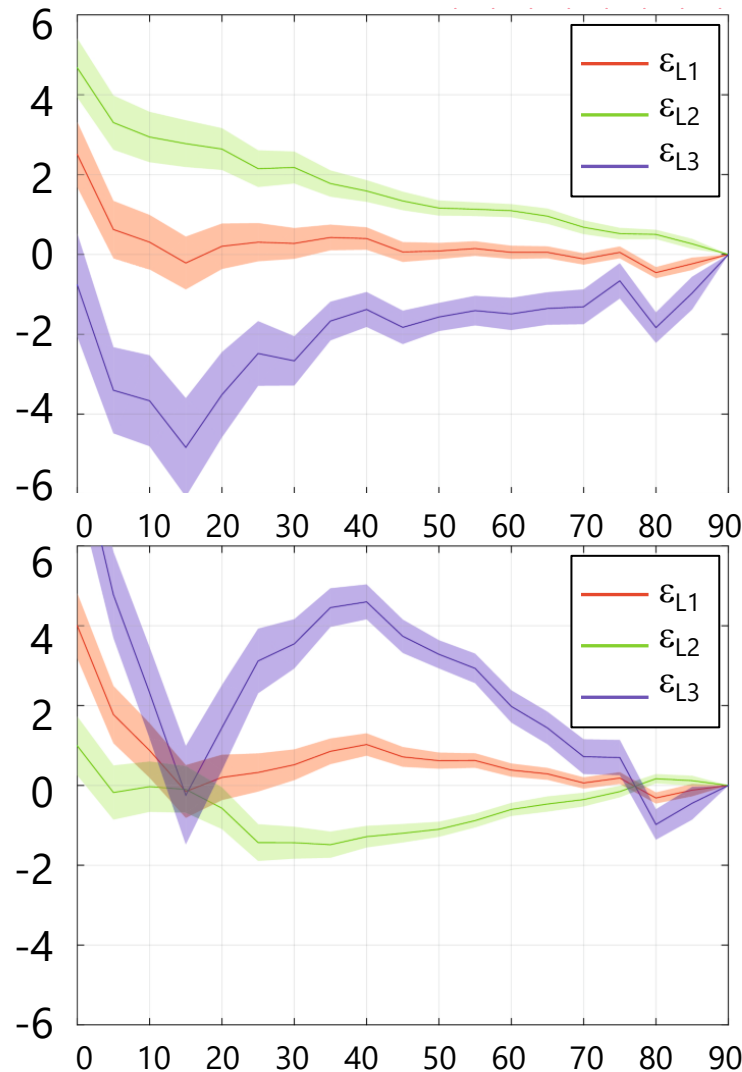
- Satellites observed at different antenna-frame elevations can be used to quantify the errors in the calibration**

Two different calibration schemes examined

- Ionosphere-free combination L3 is crucial for long distance and reference frame determinations

$$\Phi_{L3} = \frac{f_1^2 \Phi_{L1} - f_2^2 \Phi_{L2}}{f_1^2 - f_2^2}$$

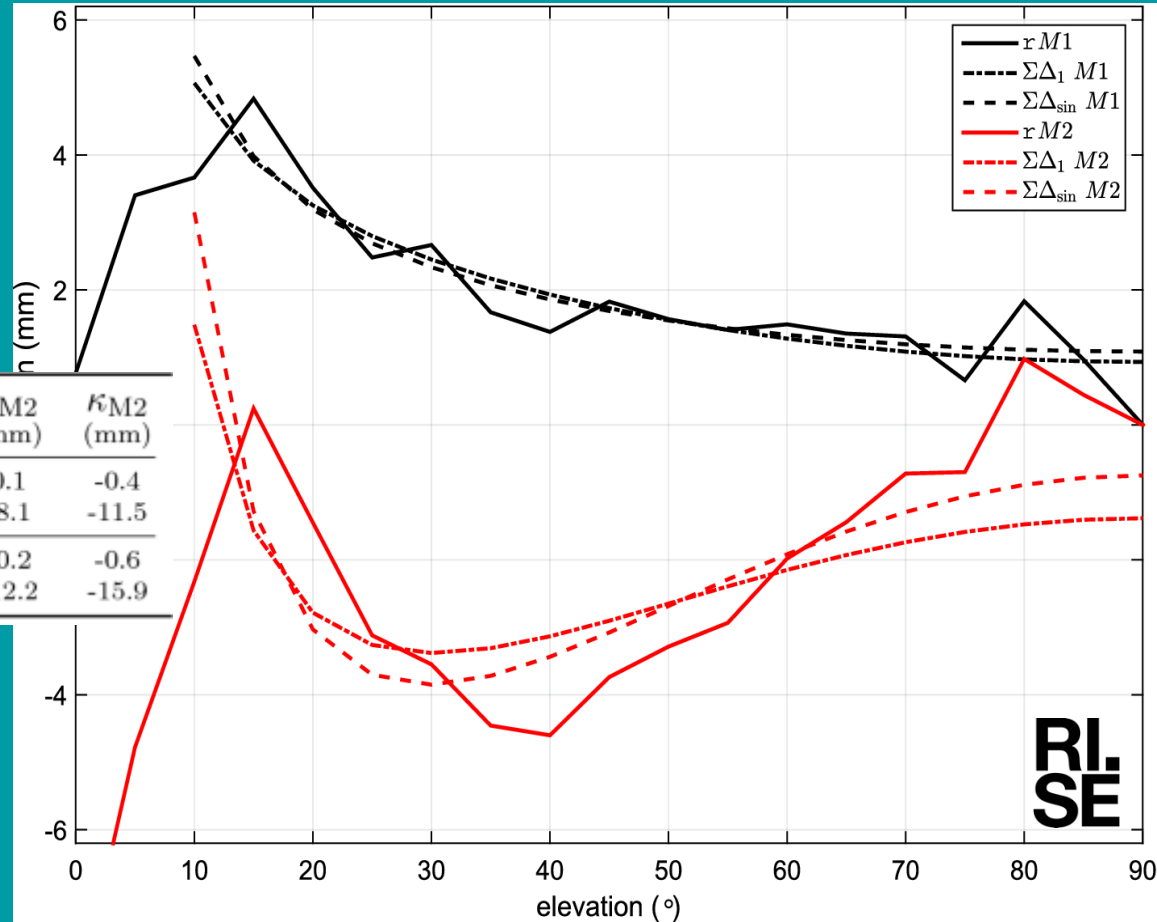
- Opposite errors on L1 and L2 are constructive, i.e. detrimental for L3
- Calibration errors alias as a combination of troposphere and height



Calibration error estimated as combination

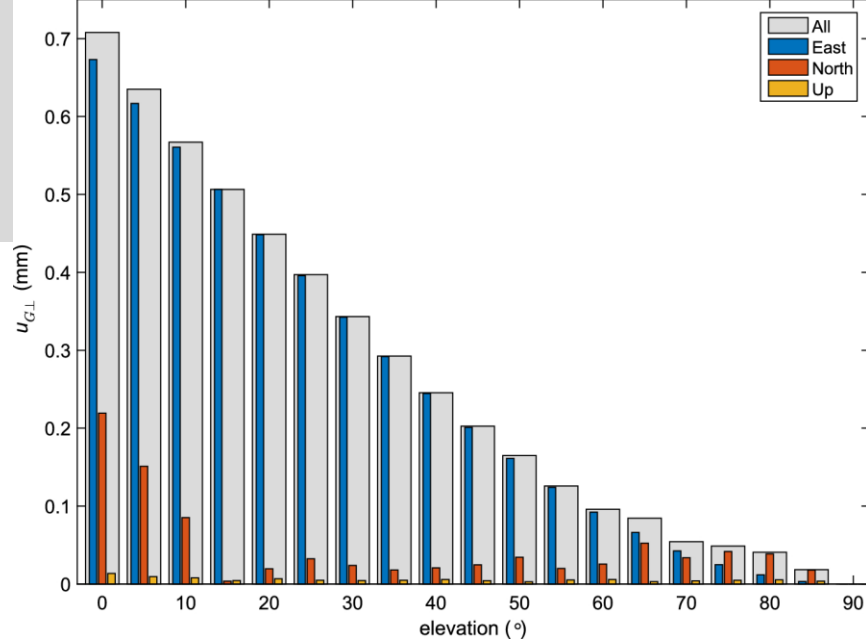
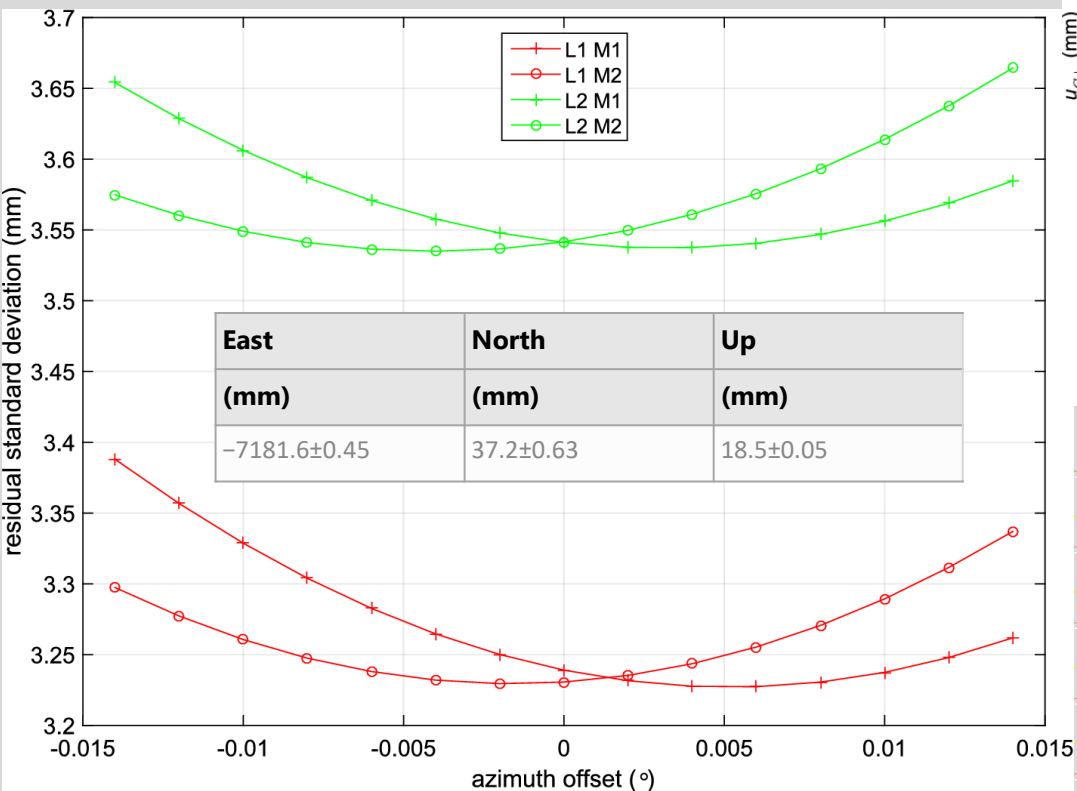
- Troposphere
- Vertical
- Clock

Map \ Alias		θ_{M1} (mm)	ν_{M1} (mm)	κ_{M1} (mm)	θ_{M2} (mm)	ν_{M2} (mm)	κ_{M2} (mm)
$w(1) : L1$	$\mapsto$	-	-0.2	-0.3	-	0.1	-0.4
$w(1) : L3$	$\mapsto$	0.5	2.0	2.4	2.1	-8.1	-11.5
$w(\sin \epsilon) : L1$	$\mapsto$	-	-0.4	-0.4	-	-0.2	-0.6
$w(\sin \epsilon) : L3$	$\mapsto$	0.8	1.0	1.3	3.0	-12.2	-15.9

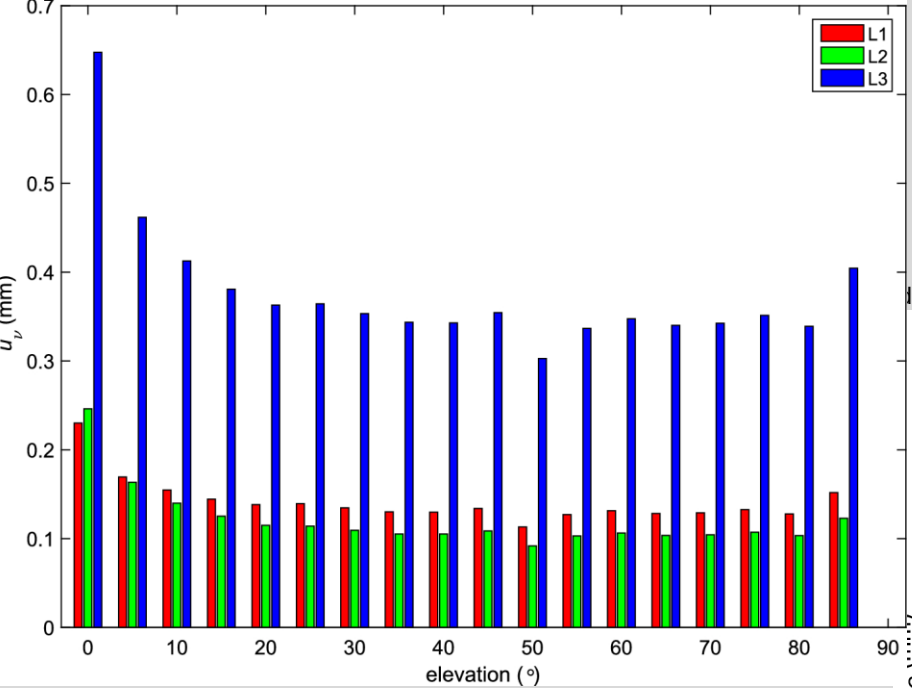


Processing and uncertainties

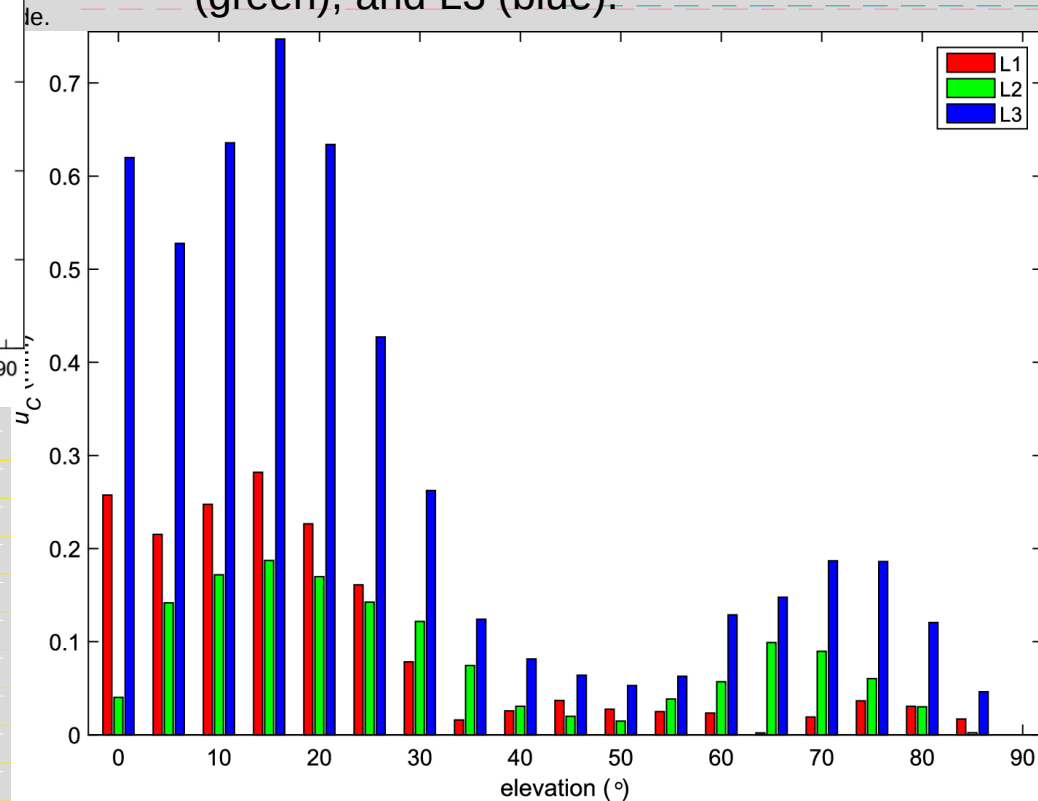
Baseline orientation



Uncertainties $u_{G\perp}$ of the calibration error estimates ε due to uncertainties in the east, north and up directions individually.



- Uncertainties u_C of the **method error estimates** due to the stochastic variations in individual calibration results at L1 (red), L2 (green), and L3 (blue).



- Uncertainties $u_{\lambda v}$ of the **calibration error estimates** for M1 and M2 at L1 (red), L2 (green), and L3 (blue).

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