High Quality Zenith Tropospheric Delay Estimation

Using a Low-Cost Dual-Frequency Receiver and Relative Antenna Calibration

This Display is based on Krietemeyer et al., 2020
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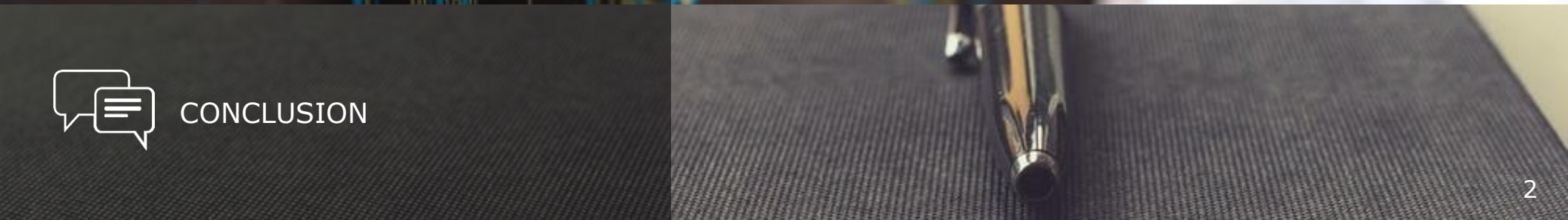
A. Krietemeyer, H. v. d. Marel, N. v. d. Giesen, M.-C. t. Veldhuis
E-mail contact: A.Krietemeyer@tudelft.nl

INTRODUCTION

METHODS

RESULTS



CONCLUSION

High quality ZTD estimations typically rely on high-grade equipment

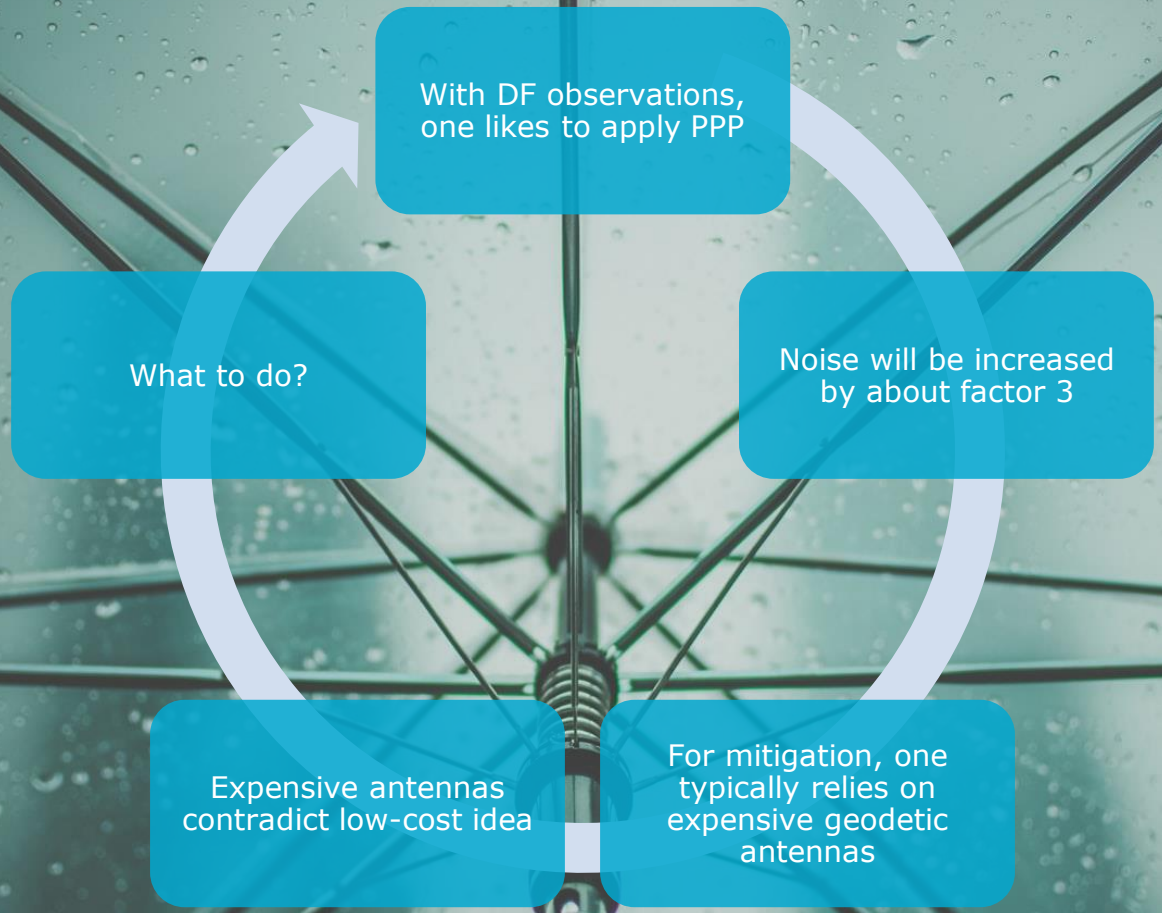
In certain areas high grade equipment is only sparsely available

Previously low-cost only possible with SF receivers

Low-cost DF receivers released

DF frequency measurements avoid 'complicated' methods to estimate ZTD

Can low-cost dual frequency receivers also obtain high quality ZTD estimations?


With DF observations, one likes to apply PPP
Noise will be increased by about factor 3
For mitigation, one typically relies on expensive geodetic antennas
Expensive antennas contradict low-cost idea
What to do?

~~MONEY, MONEY, MONEY~~

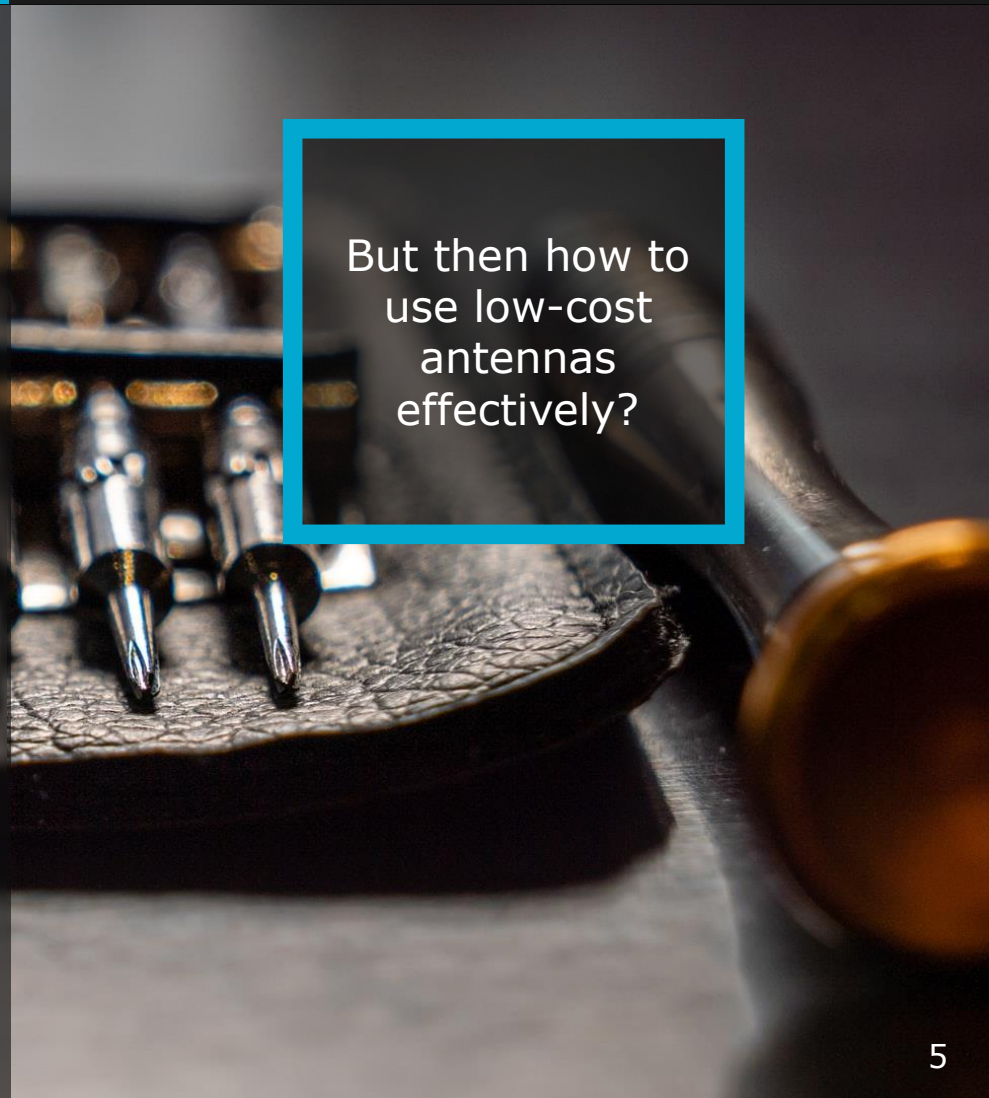
To be 'really low cost', also low-cost antennas are needed

Low-cost antennas are generally not calibrated

Geodetic antennas are typically calibrated which is expensive

Our approach: apply a relative antenna calibration and generate absolute antenna patterns

We show PPP-derived ZTD results with a ZED F9P receiver and different antennas



But then how to use low-cost antennas effectively?

METHOD – OVERVIEW

A relative antenna calibration based on a short-baseline experiment is performed to correct for the antenna Phase Center Variations (PCVs).

TWO approaches:

A) An elevation-only calibration by averaging over all azimuth angles

B) An azimuth-elevation calibration

To transform the relative calibrations resulting from the short-baseline to absolute PCVs, the known base station antenna PCVs are added to the residuals.

For this, new ANTEX entries using a binning width of 5° are created.

METHOD – OVERVIEW

Several tests are performed with all utilized antennas and different ANTEX configurations:

- No ANTEX file at all
- Satellite PCO/PCVs only
- IGS Type mean receiver ANTEX (only available for LEIAR25.R3 and Zephyr2)
- Own elevation-only receiver ANTEX
- Own azimuth-elevation receiver ANTEX

The ZTD performance is evaluated against the IGS ZTD reference data from the IGS station DLF1 (10m distance).

EXPERIMENT

- Delft, next to IGS station DLF1
- Short baseline of ~ 10m (DLF1 is the base station)
- Same observation point consecutively measured
- Near-field and multipath can be regarded as relatively clean
- Three full observation days

EQUIPMENT

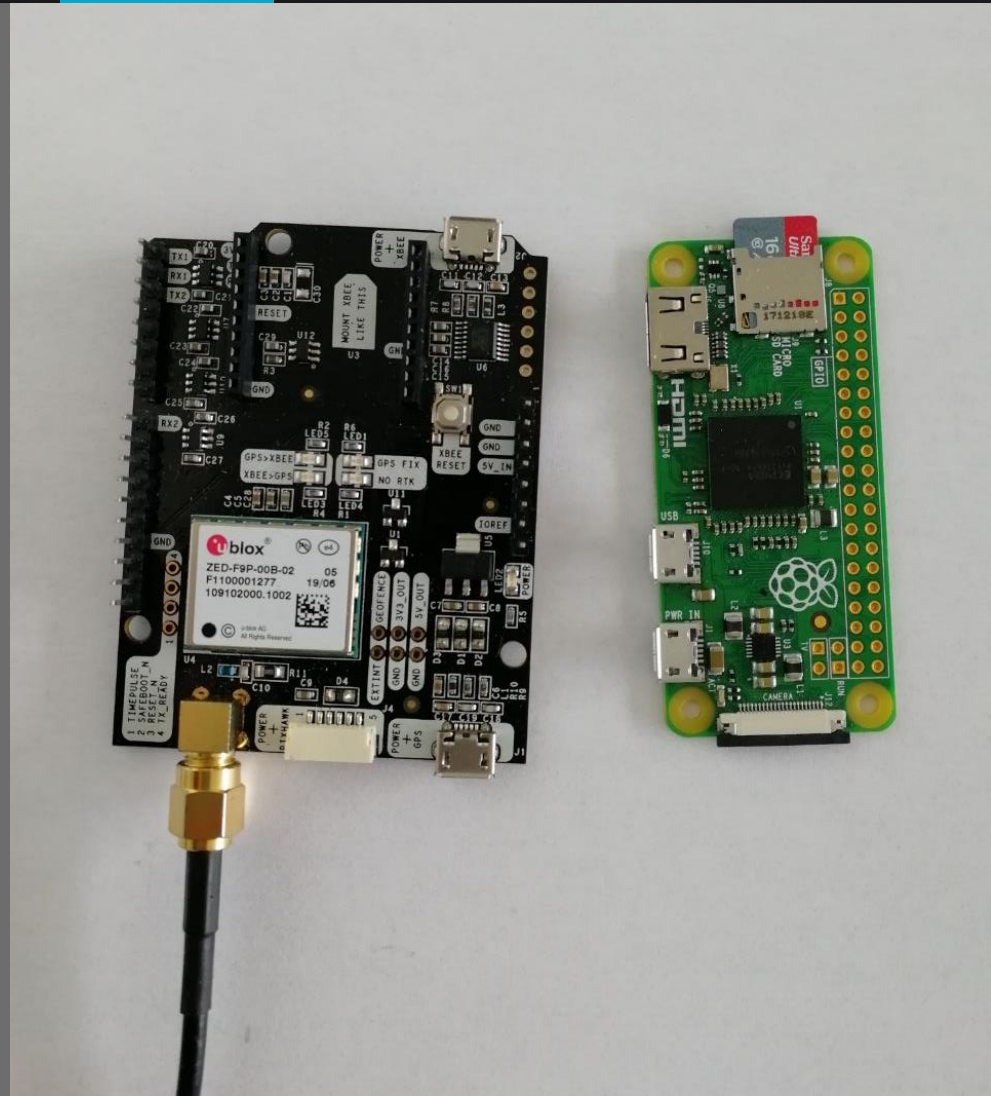
ZED-F9P receiver
Data logging Raspi Zero, water proof case

~ 200 €

LEIAR25.R3 LEIT
TRM55971.00 NONE (Zephyr2 Geodetic)
Trimble GA530
Trimble AV28
U-blox ANN-MB-00

Antenna price range
50 - ~2000 €

Different antenna brackets driven by different designs



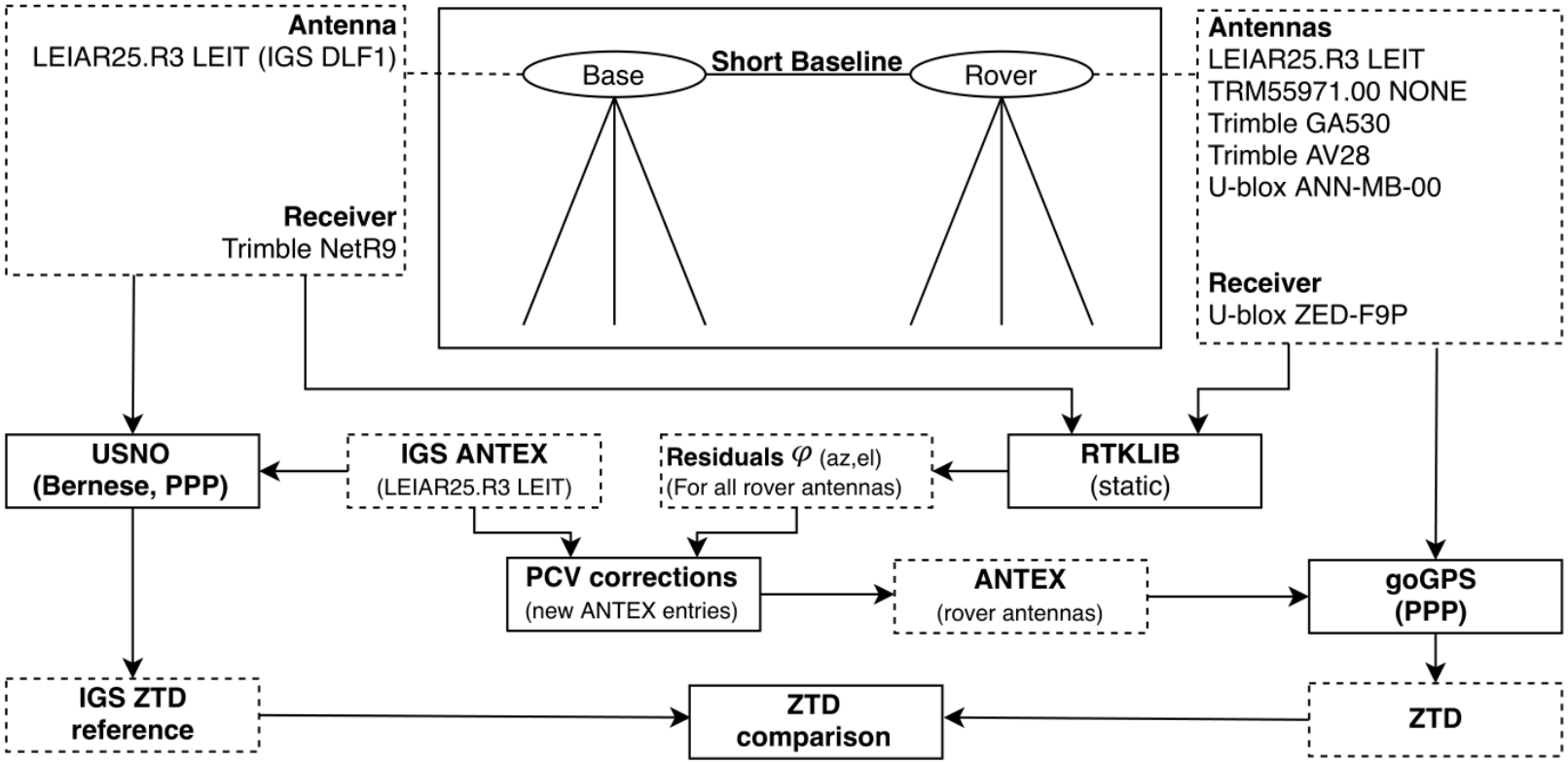
EQUIPMENT

a) LEIAR25.R3 LEIT with DLF1 in background
b) Trimble Zephyr2 geodetic
c) Trimble GA530
d) Trimble AV28
e) U-blox ANN-MB-00

The antennas AV28 (d) and ANN-MB-00 (e) are shown with a circular plane. A second measurement is performed with a metallic rectangular bracket

The antennas are ordered by the approximate price

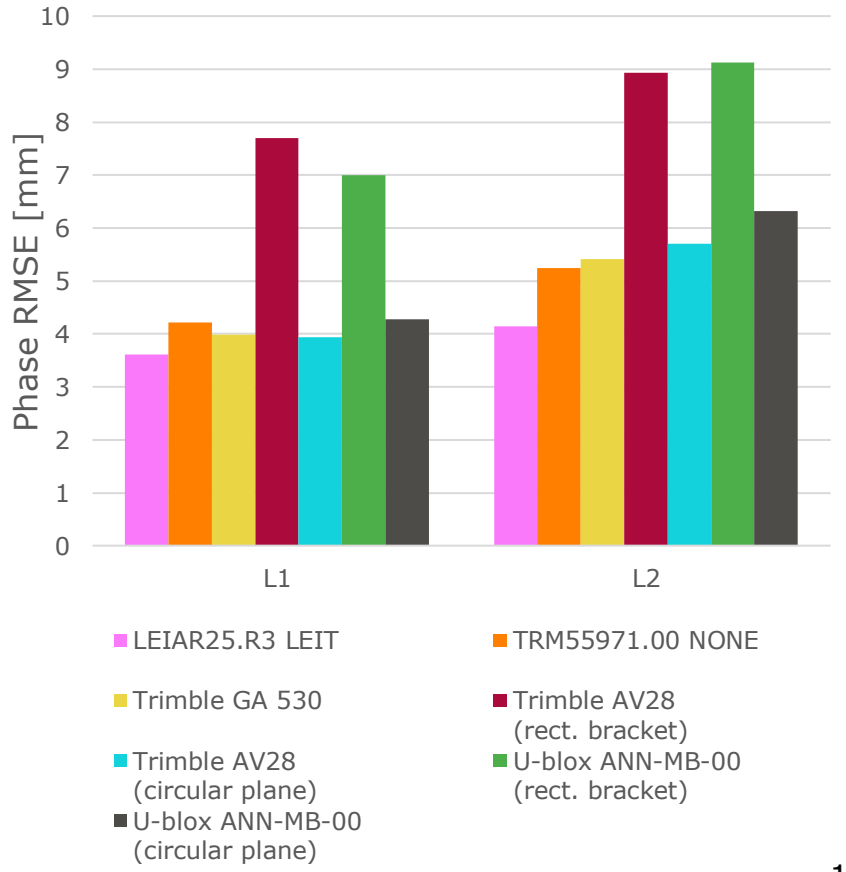
SCHEMATIC APPROACH



The calibration procedure relies on residual analysis

RESIDUALS BEFORE CORRECTION

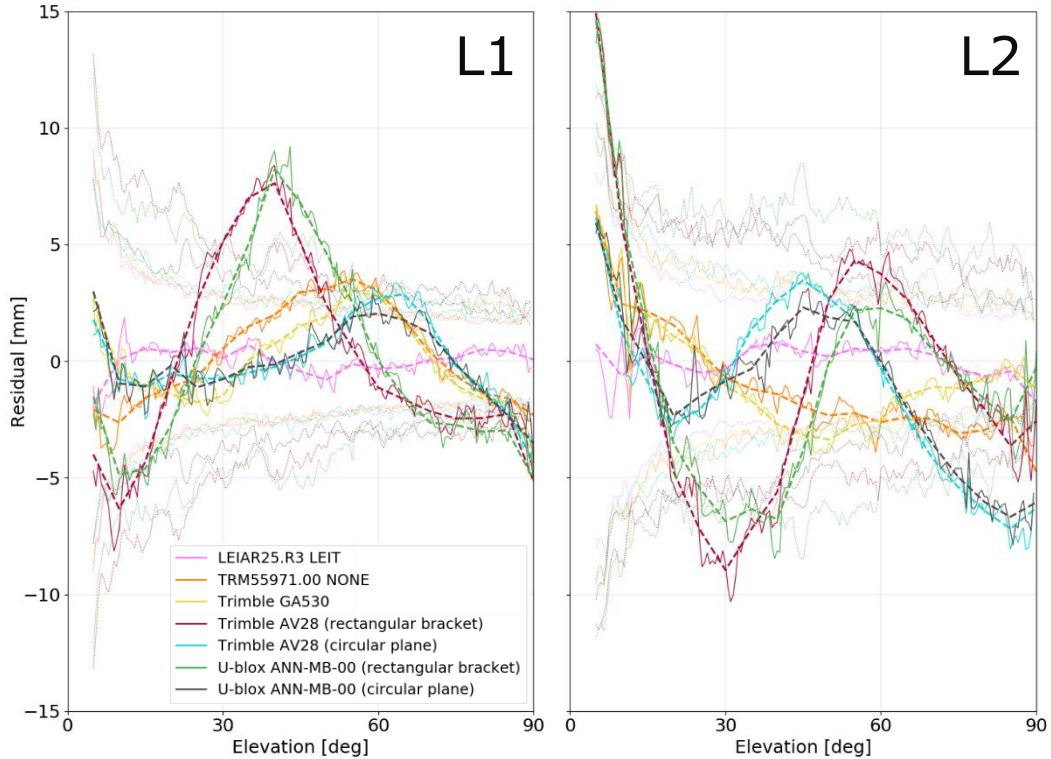
- RMSE of phase residuals on L1 and L2
- Bars are ordered by price of the antenna
- Generally lowest residuals for highest priced antenna
- Lower cost antennas AV28 and ANN-MB-00 perform better when a circular ground plane is used



CARRIER PHASE RESIDUALS VS ELEVATION

Graph explanation:
- 0.5 degree averages (continuous lines)
- 5 degree averages (the ANTEX standard; thick dotted line)
- Standard deviation (thin dots)

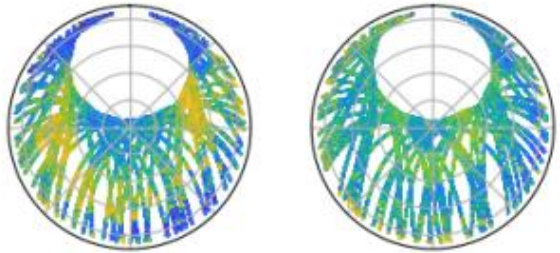
Graph findings:
- LEIAR25.R3 (pink line) close to zero
- Clear strong signal evident for AV28 and ANN-MB-00 when a metallic rectangular bracket is used. With a circular plane, the residuals are smaller



RECTANGULAR VS CIRCULAR GROUND PLANE

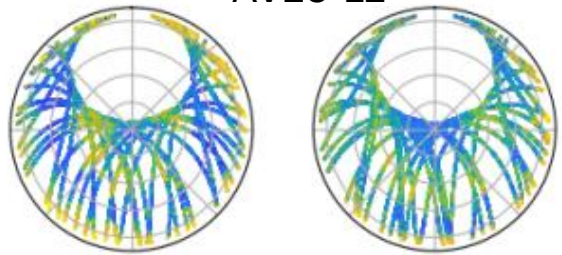
- Residuals plotted in azimuth-elevation bins
- High residuals when a rectangular bracket is used. More uniform with a circular ground plane.
- For calibration, gaps have to be filled
- For the azimuthal averaging, less confidence is given

AV28 L1



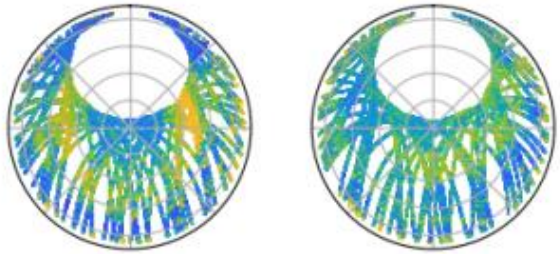
Rectangular (left), circular (right)

AV28 L2



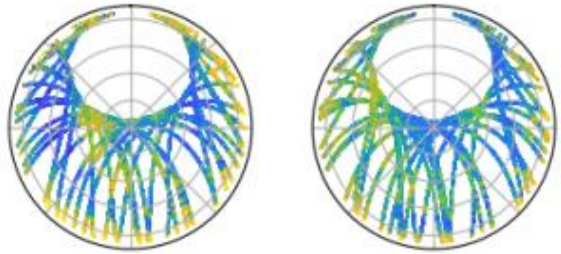
Rectangular (left), circular (right)

ANN-MB-00 L1

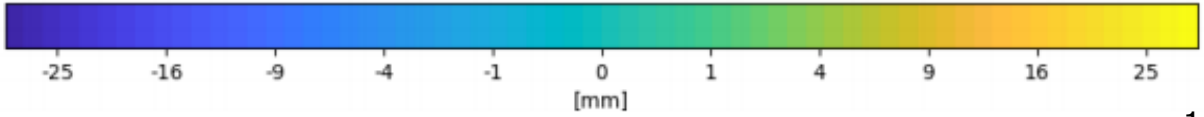


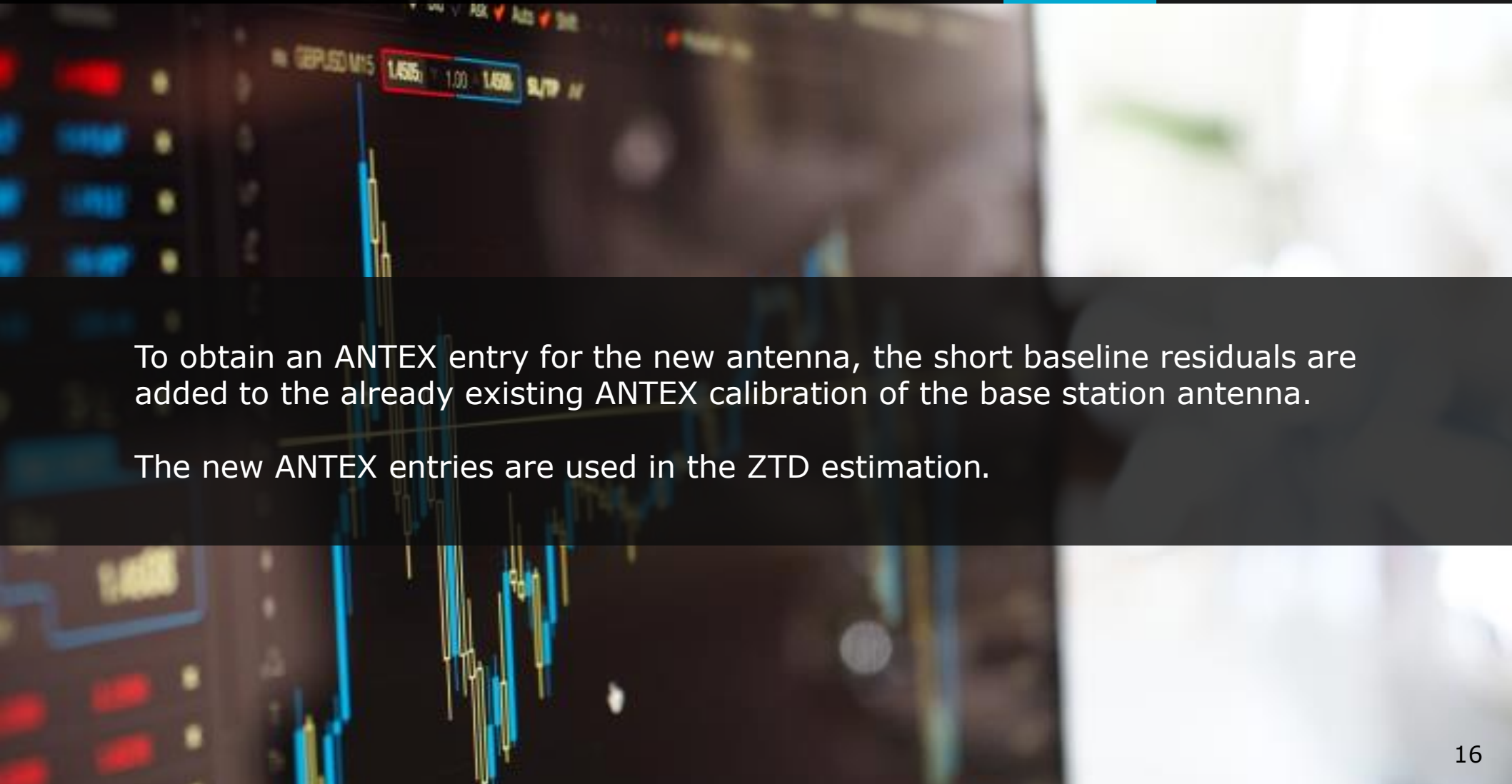
Rectangular (left), circular (right)

ANN-MB-00 L2



Rectangular (left), circular (right)

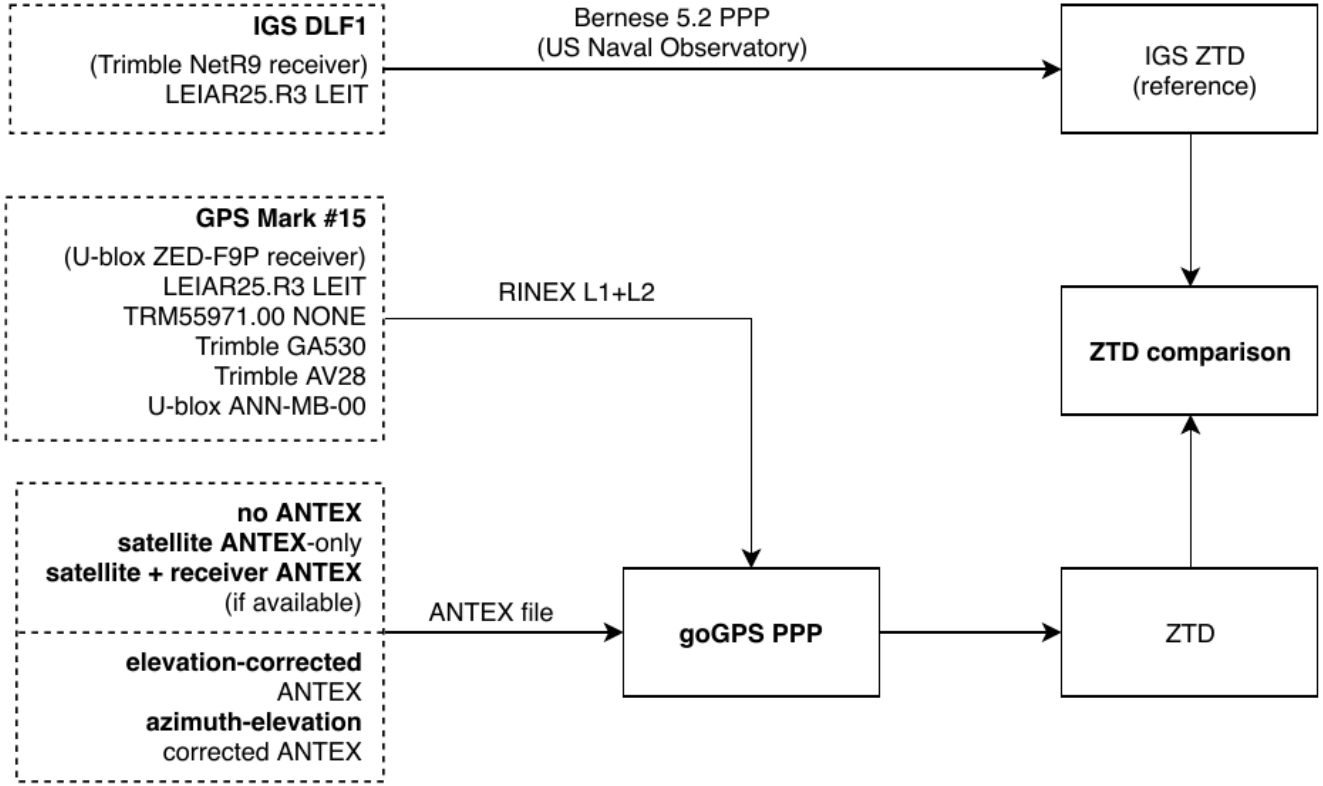




To obtain an ANTEX entry for the new antenna, the short baseline residuals are added to the already existing ANTEX calibration of the base station antenna.

The new ANTEX entries are used in the ZTD estimation.

ZTD EVALUATION



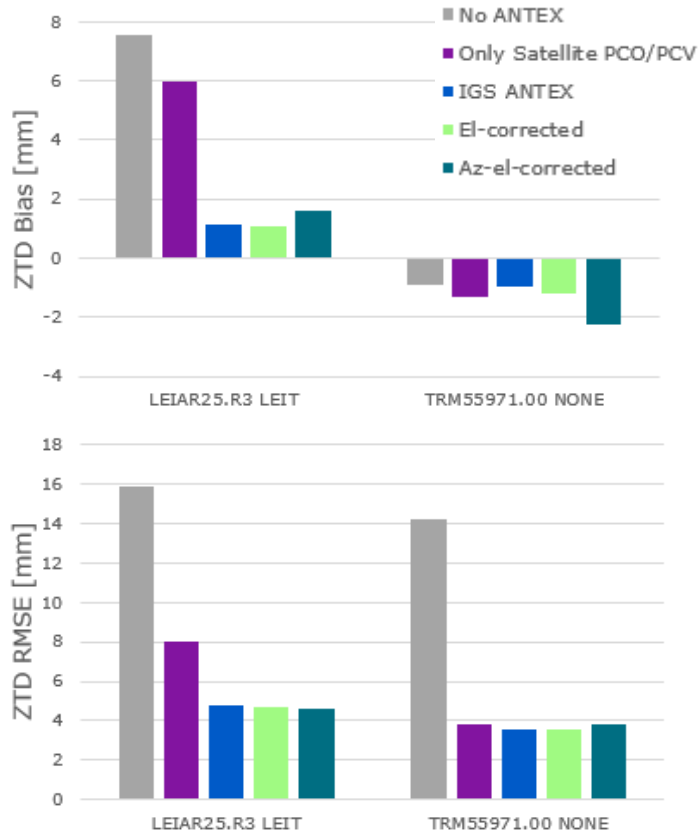
REFERENCE ANTENNA ZTD RESULTS

Mean ANTEX entries for these two antennas have been used for additional verification

ZTDs were estimated with goGPS and compared to IGS ZTD stations for DLF1
(10 meters from test site)

No difference in performance between our calibration results and the type mean ANTEX entries

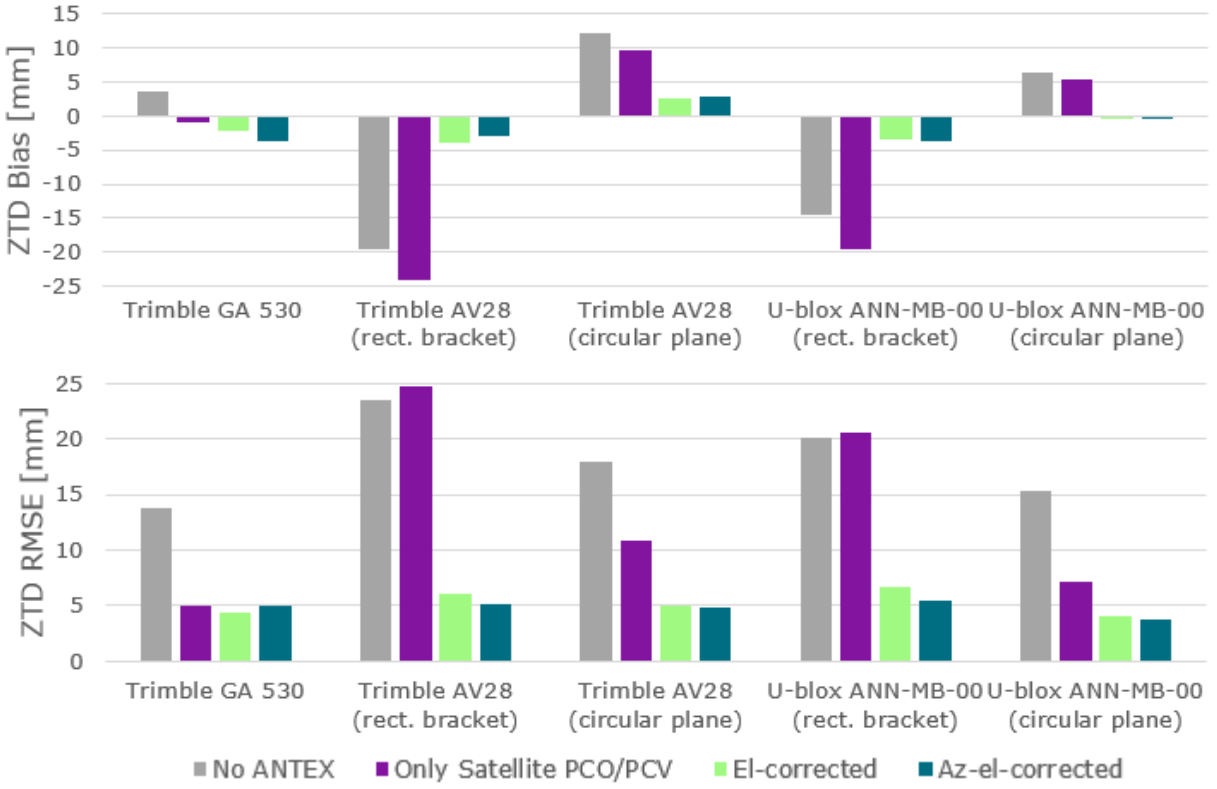
El.-only dependent calibration is performing better than the Az.-el. dependent calibration



OTHER ANTENNAS

Applying the calibrations to the other antennas results in a significant improvement especially for the observations with a rectangular bracket

The ANN-MB-00 calibrated measurements with a circular plane performed best in our scenario

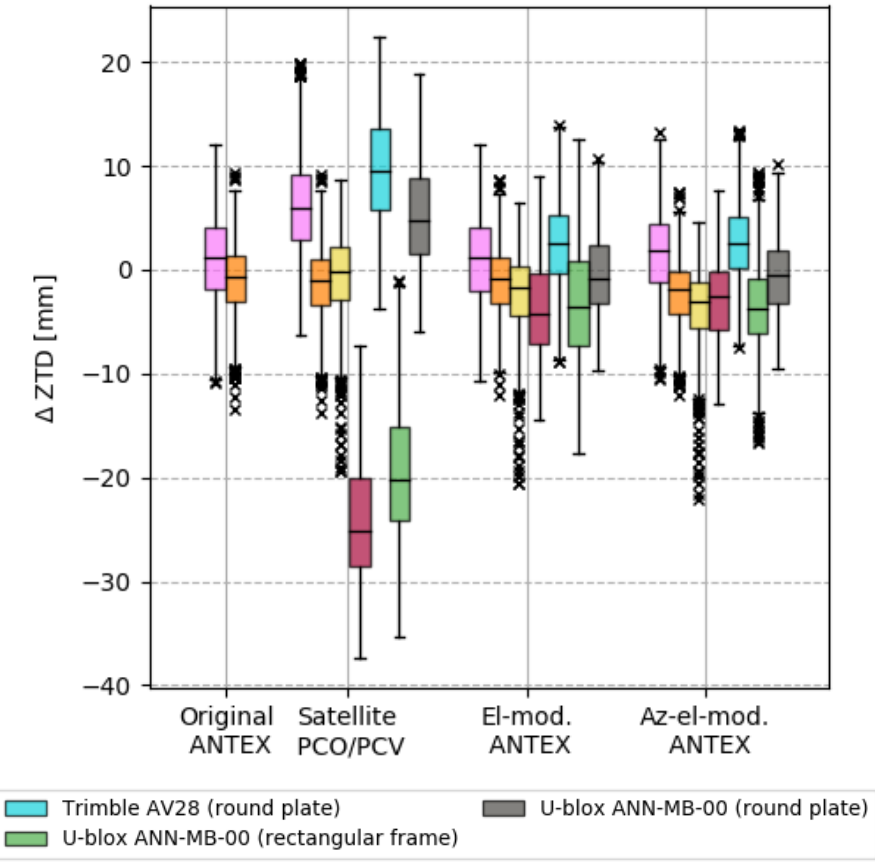


SUMMARY

Improvements of the calibration on dual-frequency observations illustrated in boxplots

We also applied our corrections using only single-frequency observations in a second run. Its ZTD estimations are of comparable quality to the reference values.

Results for this can be found in the article:
Krietemeyer et al., 2020
https://doi.org/10.3390/rs12091393



HIGH QUALITY ZTD ESTIMATION DOES NOT HAVE TO BE EXPENSIVE

- **Without calibrations** ZTD estimations with the low-cost antennas are not practical
- **With calibrations** ZTD accuracy improves to a level that is valuable for meteorological applications (RMSE ~4 mm)
- Results in ZTD estimations are of similar quality as high-grade antennas
- The cost of the calibration is of the same order as the equipment cost and could even be performed in the field
- Elevation-only approach is more robust than the azimuth-elevation maps. The latter one requires further work