



Royal Netherlands Meteorological Institute Ministry of Infrastructure and Water Management

High-quality ZTD estimation with cost-effective equipment and in-field antenna calibrations

Workshop on **GNSS and new applications** 20 May 2022

Andreas Krietemeyer









ESTIMATIONS

done with high-grade geodetic stations

EQUIPMENT

receivers and antennas very expensive

MEASUREMENTS

in high quality

TRADITIONAL GNSS







EQUIPMENT

requiring a fraction of the ourchase costs of traditional GNSS equipment

COST-EFFICIENT GNSS



RESEARCH GOAL

aimed towards Global South were much less stations are available





ZTD ESTIMATION



POSITIONING

FOCUS ON TWO PARAMETERS





COST-EFFICIENT ZTD ESTIMATION



To be really cost-efficient, also cost-efficient antennas are needed

Geodetic antennas are typically calibrated which is expensive

BEING COST-EFFICIENT

Royal Netherlands Meteorological Institute May 30, 2022

Cost-efficient antennas are generally not calibrated

OUR APPROACH apply a relative antenna

calibration and generate absolute antenna patterns



ANTENNA PHASE CALIBRATION







- A relative antenna calibration based on a short-baseline experiment is performed to correct for the antenna Phase Center Variations (PCVs).
- An elevation-only calibration by averaging over all azimuth angles
- 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 are created.
- > RINEX carrier phase data is modified.





- Several tests are performed with all utilized antennas and different ANTEX configurations (PPP):
 - No ANTEX file at all
 - Satellite PCO/PCVs only
 - Own elevation-only receiver ANTEX
- The ZTD performance is evaluated against the IGS ZTD reference data from the IGS station DLF1 (10m distance).



Royal Netherlands Meteorological Institute May 30, 2022

ANTENNA **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





Royal Netherlands Meteorological Institute May 30, 2022

EQUIPMENT

- a) LEIAR25.R3 LEIT, 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



RESIDUALS ON L1 WITH DIFFERENT ANTENNAS





RECTANGULAR VS CIRCULAR GROUND PLANE







IMPACT OF THE CALIBRATION ON THE **SEMIVARIANCES**





L1 RESIDUALS [MM] BEFORE AND AFTER CALIBRATION



Original RINEX 1° corr.

CONCLUSION RESIDUALS

- Carrier phase residuals of the lowcost antennas are reduced by 11– 34% on L1 and 19–39% on L2
- Greatest improvements on antennas with a rectangular bracket
- Cost-efficient antennas higher residuals, but improved



REFERENCE ANTENNA ZTD RESULTS [MM]









ZTD BIAS [MM]





ZTD RMSE [MM]



CONCLUSION **ZTD ESTIMATIONS**

- 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

<u> Aŭ</u>

POSITIONING

- Using the same principle as for the ZTD estimation
- Created ANTEX files for each antenna and modified RINEX phase data according to entries
- > Use PPP (NRCan) for daily positioning
- Use RTKLIB for kinematic positioning (mainly targeted for deformation monitoring)
- Meaning that offsets / biases are of lesser interest, but the movement over time is more important



PPP OFFSETS (VERTICAL COMPONENT) [MM] BEFORE AND AFTER CALIBRATION



23



KINEMATIC VERTICAL COMPONENT MADs [MM] BEFORE AND AFTER CALIBRATION



CONCLUSION POSITIONING

- The calibration reduces the Median Absolute Deviations (MADs) of the low-cost antennas in the vertical direction using Post Processed Kinematic (PPK) by 20–24%
- For the cheapest antenna, the MAD is reduced from 5.6 to 3.8 mm, comparable to a geodetic-grade antenna (3.5 mm MAD)
- The calibration also has a positive impact on the Precise Point Positioning (PPP) results, delivering more precise results and reducing height biases



https://gnss-antcal.citg.tudelft.nl

	SELECT FILES TO UPLOAD	Home
	Base station RINEX file: Choose File No file chosen	
	Rover station RINEX file: Choose File No file chosen	
	Your e-mail address:	
	Show optional fields:	
	□ I give consent to process and store the uploaded data by TU Delft for further research activities.	
	Submit	
	Please note that software errors may still exist. We provide this service on an 'as is' basis, and no warrant either express or implied, is given on the results. The use of the service is at your sole risk.	У,
EBSITE		



- Currently an experimental setup (4 stations) installed on Saba, Dutch Caribbean
- Investigating usefulness for volcano monitoring



IN **PRACTICE**

Thank you



Further reading

- High Quality Zenith Tropospheric Delay Estimation Using a Low-Cost Dual-Frequency Receiver and Relative Antenna Calibration (Editor's Choice), Krietemeyer et al., 2020
 - <u>https://www.mdpi.com/2072-4292/12/9/1393</u>
- A Field Calibration Solution to Achieve High-Grade-Level Performance for Low-Cost Dual-Frequency GNSS Receiver and Antennas, Krietemeyer et al., 2022
 - https://www.mdpi.com/1424-8220/22/6/2267