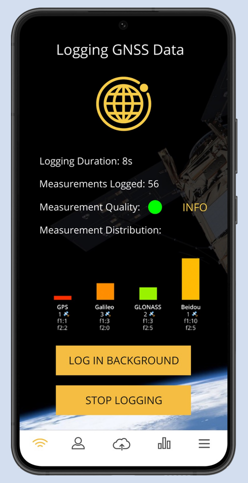
Troposphere Monitoring Based on Crowdsourced Smartphone GNSS Data

Yuanxin Pan[1], Grzegorz Kłopotek[1], Markus Rothacher[1], Linda See[2], Rudi Weinacker[2], Tobias Sturn[2], Ian McCallum[2], Vicente Navarro[3], Benedikt Soja[1]

[1]Institute of Geodesy and Photogrammetry, ETH Zürich; [2]International Institute for Applied Systems Analysis; [3]European Space Astronomy Center, ESA

1 Introduction

- GNSS is an essential tool for troposphere monitoring. However, geodetic-grade stations are costly, and thus cannot be densely deployed
- Android smartphones can be used to collect raw GNSS data since the release of the Android 7 OS in 2016
- A smartphone GNSS data crowdsourcing campaign was launched on March 17th 2022 as part of the CAMALIOT project[1]. The usability of these GNSS data needs to be investigated



2 Campaign Overview

- Funded by ESA (NAVISP-EL1-038.2), in collaboration with IIASA
- Started on March 17th 2022
- About 12 thousand users participated worldwide
- About 5 TB data (compressed gnsslogger file) was collected
- More than 98% of the data was collected indoors with low SNR
- Data collected outdoors usually lasted for 3-10 minutes
- Samsung smartphones contributed most high-quality data
- The 2nd frequency data was quite limited and not always usable

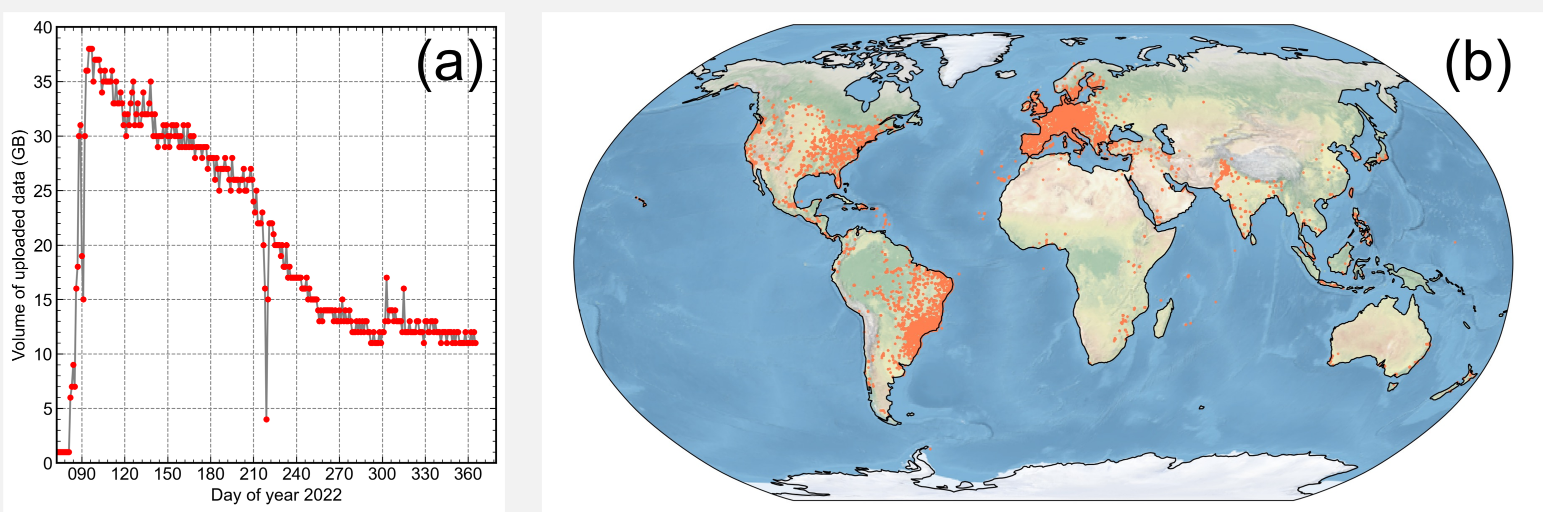


Figure 1 **(a)** Daily uploaded data volume since March 17th. **(b)** Distribution of crowdsourced smartphone data

3 Method

Quality Control

- Quality indicators, such as SNR, PDOP, noise level derived from time-differenced carrier phase, were used to select high-quality data

ZTD Estimation

- Software: CamaliotGNSS was developed and used
- Relative positioning in static mode with a Kalman filter/smoother
- Constellations: GPS (L1/L2) + Galileo (E1/E5)
- Troposphere: Estimation of differential ZTD (dZTD) with respect to geodetic stations
- Ionosphere: Ignored for short baselines. L2/E5 data was interpolated with the SEID method[2] for GPS/Galileo to implement ionosphere-free (IF) linear combination for long baselines.

3 Results

Short Baseline (1.5 km)

- The reference dZTDs were computed between the GNSS station on Prime Tower and ETH2 (scaled with height difference)
- The dZTDs between smartphone and ETH2 station were mainly caused by the height difference (~ 40 m)

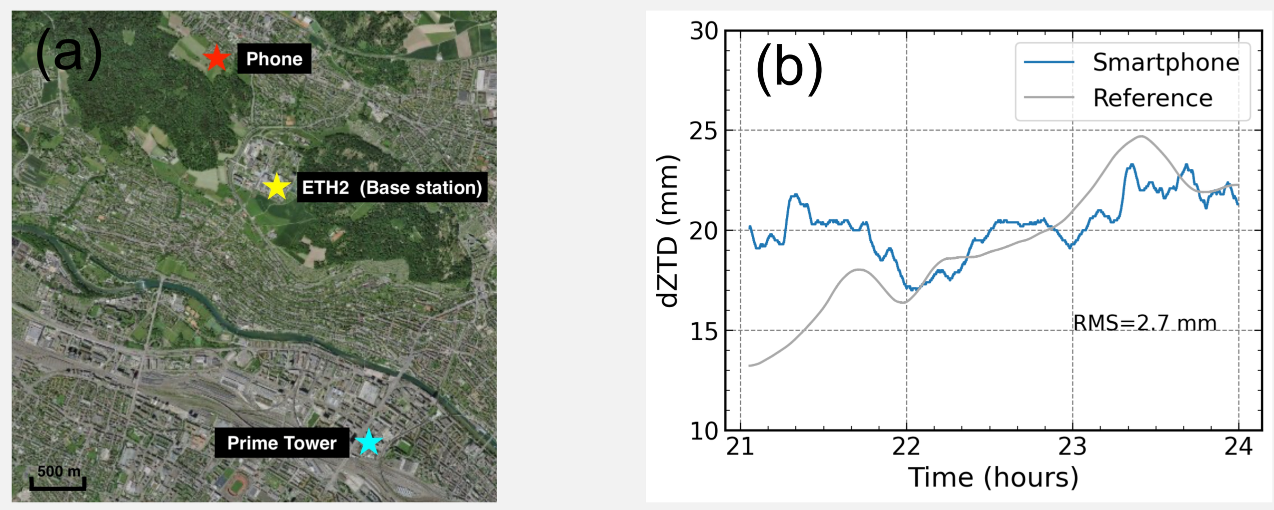


Figure 2 **(a)** Distribution of the GNSS stations used for data processing. **(b)** Time series of dZTD derived from a smartphone and a nearby geodetic-grade station (Prime Tower). ETH2 was used as base station.

Long Baseline (32 km)

- The reference dZTDs were computed between ETH2 and FRI3 (base)
- The L2/E5 data for smartphone was interpolated with the SEID method

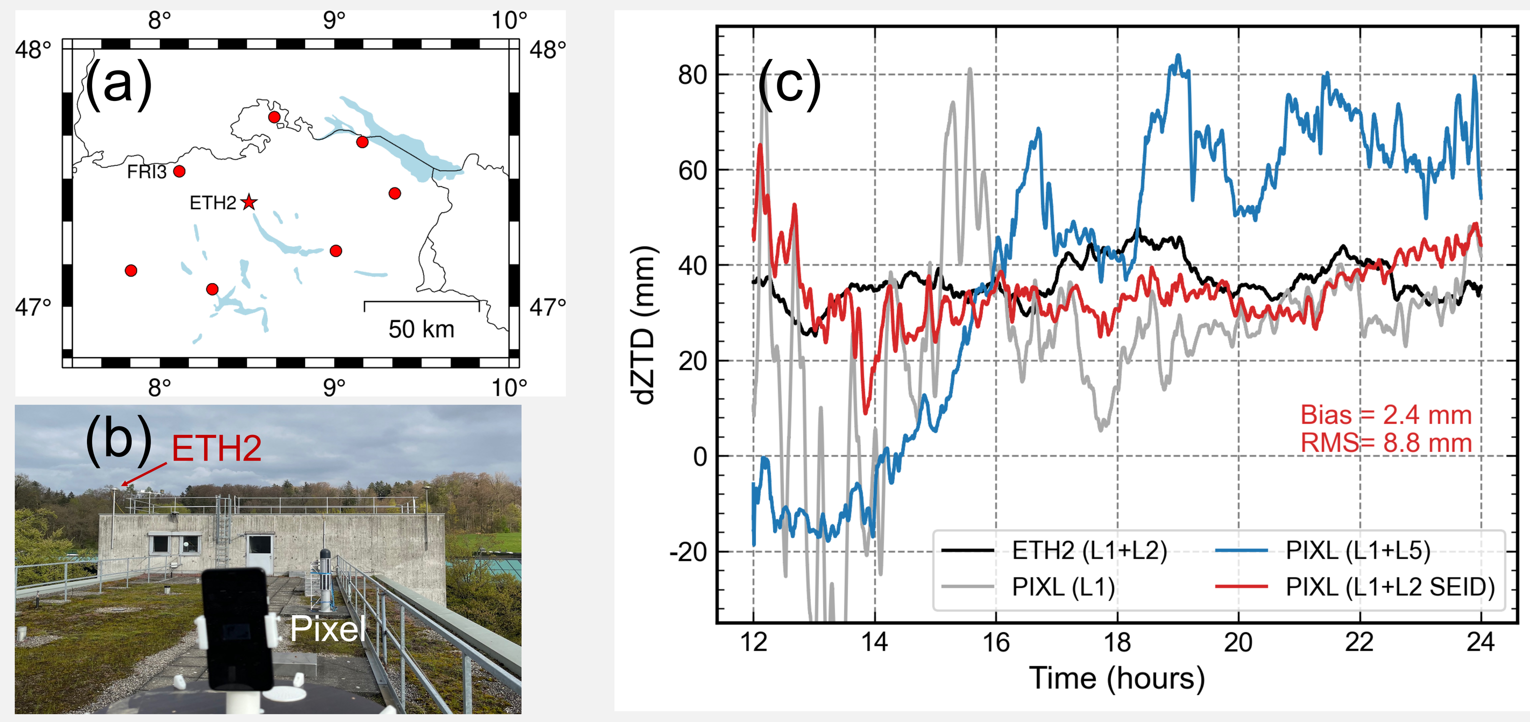


Figure 3 **(a)** Geodetic stations used for L2/E5 data interpolation. **(b)** A photo showing the relative position of the Pixel smartphone and ETH2 station. **(c)** dZTD estimations with different strategies.

5 Conclusion

- Troposphere delay derived from smartphone data can achieve an accuracy of better than 1 cm
- Crowdsourced smartphone GNSS data is promising to densify the GNSS network for troposphere monitoring if it is collected in open sky
- Improvements of smartphone GNSS chip and antenna (e.g., 2nd frequency data tracking and PCV model) can further facilitate citizen science

References

1. Klopotek, G., Soja, B., & Crocetti, L., et al. (2022). Exploring Crowdsourced GNSS Observations For Data Fusion with the Use of Machine Learning. 8th International Colloquium on Scientific and Fundamental Aspects of GNSS, Sofia, Bulgaria, September 14-16.
2. Deng, Z., Bender, M., Dick, G., Ge, M., et al. (2009). Retrieving tropospheric delays from GPS networks densified with single frequency receivers. Geophysical Research Letters, 36(19).

Partner/Sponsor: