Optimal Processing of GNSS Data for Appropriate Zenith Total Delay for Climate Trend Analysis

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Context

In the framework of the IGS Repro3, 10 Analysis Centers (ACs) have reprocessed more than 20 years of GNSS data from reference ground stations all around the world, following an IGS-required processing strategy. Rebischung et al. (2024) have studied the contribution of the resulting products from all the ACs time series to the ITRF2020. To obtain an accurate positioning, the zenith tropospheric delay (ZTD) is computed as well for each station from the slant path delays depicted on Figure 1. The long lasting ZTD time series thus provided by the ACs can be useful for climate study.

However, some processing features are at the discretion of the ACs. These features can have an impact on the estimated ZTD, such as the tropospheric modeling, the cut-off angle of the elevation, or the data cleaning.

The aim of this study is to assess the differences between AC tropospheric products and test some processing strategies on one dataset.

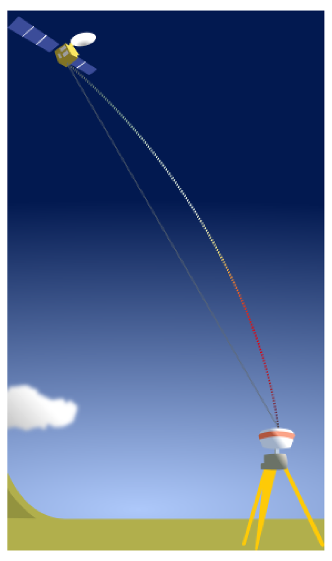
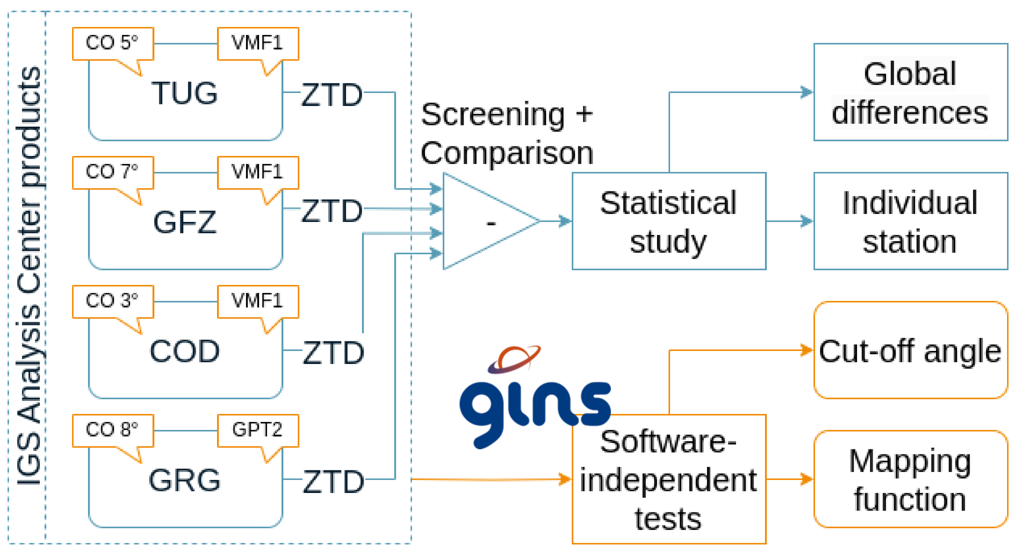


Figure 1. *Schematic of the troposphere delay in the GNSS signal propagation.*

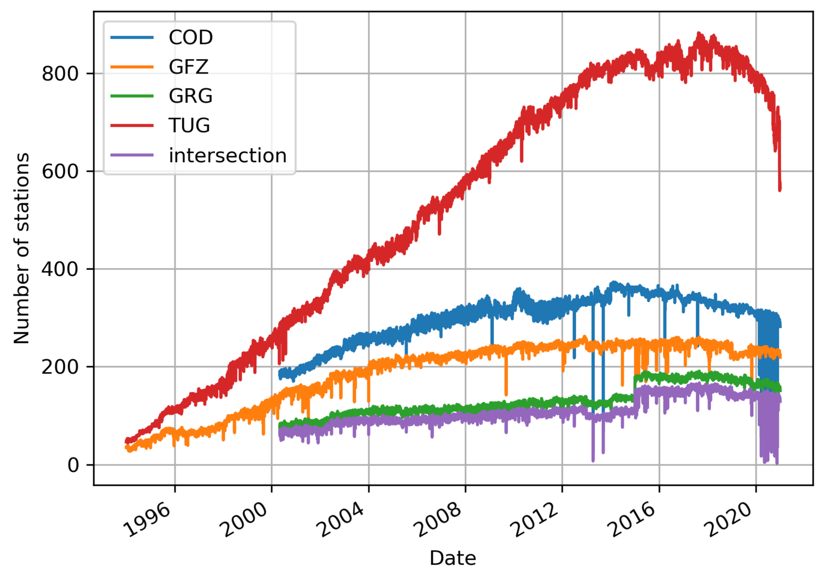
Methodology



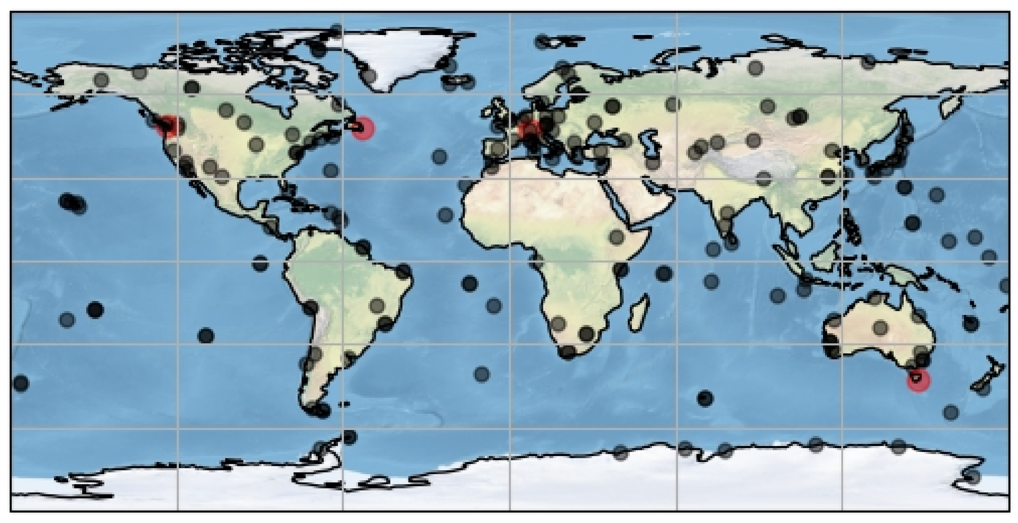
- Selection of four ACs (COD, GFZ, GRG, TUG) using different processing strategies.
- Screening of ZTD outliers and formal errors on raw tropospheric products.
- Computation of the daily average of the ZTD weighted with the formal error, and the corresponding daily standard deviation.
- Configuration tests on 5 stations (11 years: 2005 – 2015) with the GINS software (CNES) : cut-off angles, mapping function.

<u>AC comparison method :</u>

- Keeping the quadruple intersection of the AC time series.
- 200 remaining stations from May 2000 to December 2020.
- Comparison of the AC time series.



< Figure 2. *Number of stations available for each date of the ACs ZTD time series, and their intersection.*



> Figure 3. *Location of the remaining stations in the AC intersection.*

Global Comparison of the ACs

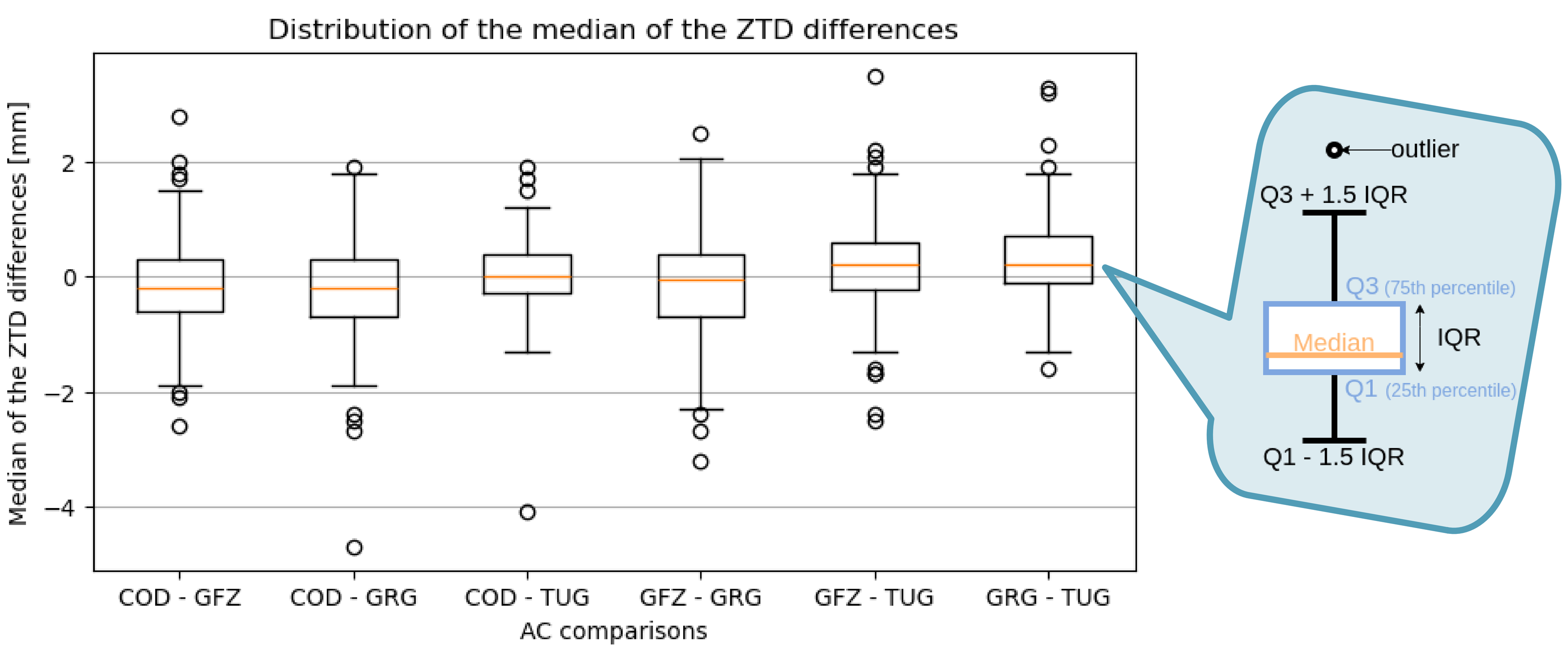


Figure 4. *Statistics of the median of the differences between the AC ZTD time series.*

- Discrepancies observed between the AC ZTD time series.
- Student test at 95 % : COD and TUG comparison is the only one not complying with the hypothesis that the mean of the difference medians is zero.
- Mood test at 95 % : None of the difference medians comply with the hypothesis that the median of the difference medians is zero.

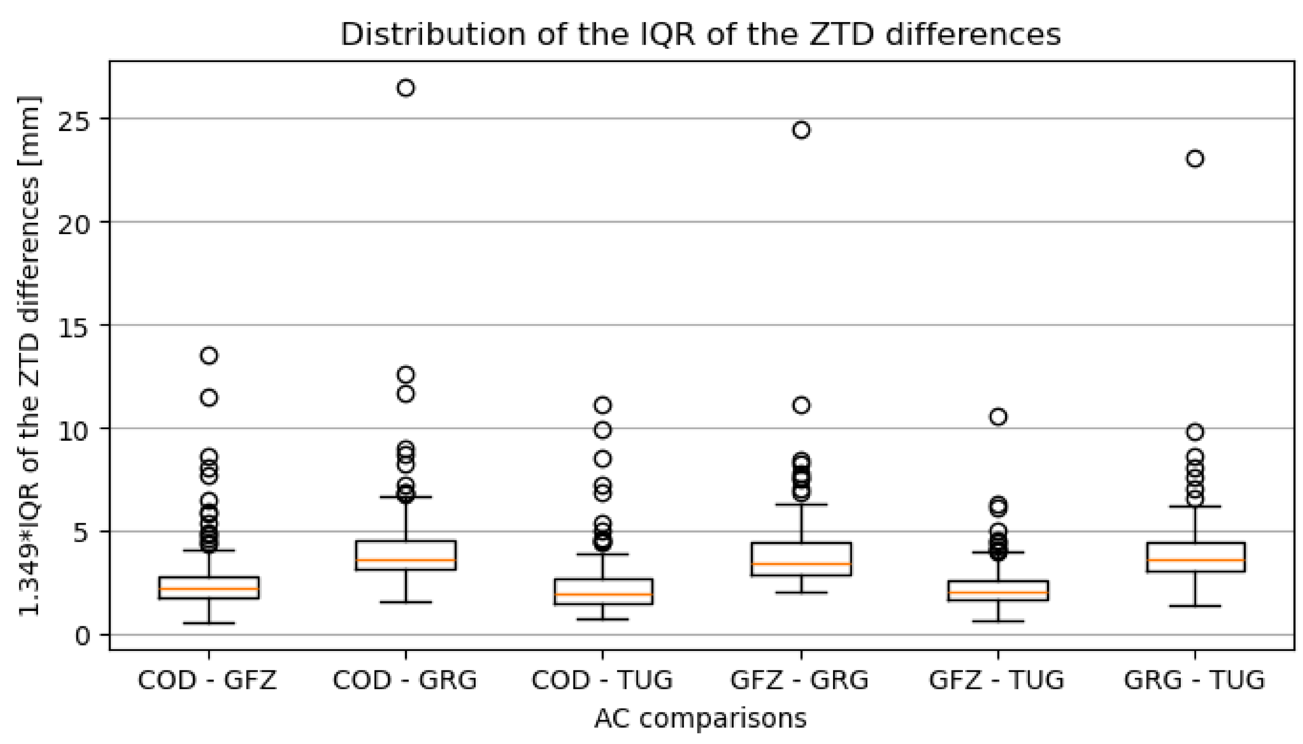


Figure 5. *Distribution of the inter-quartile range (IQR) of the ZTD differences.*

Focus on individual stations

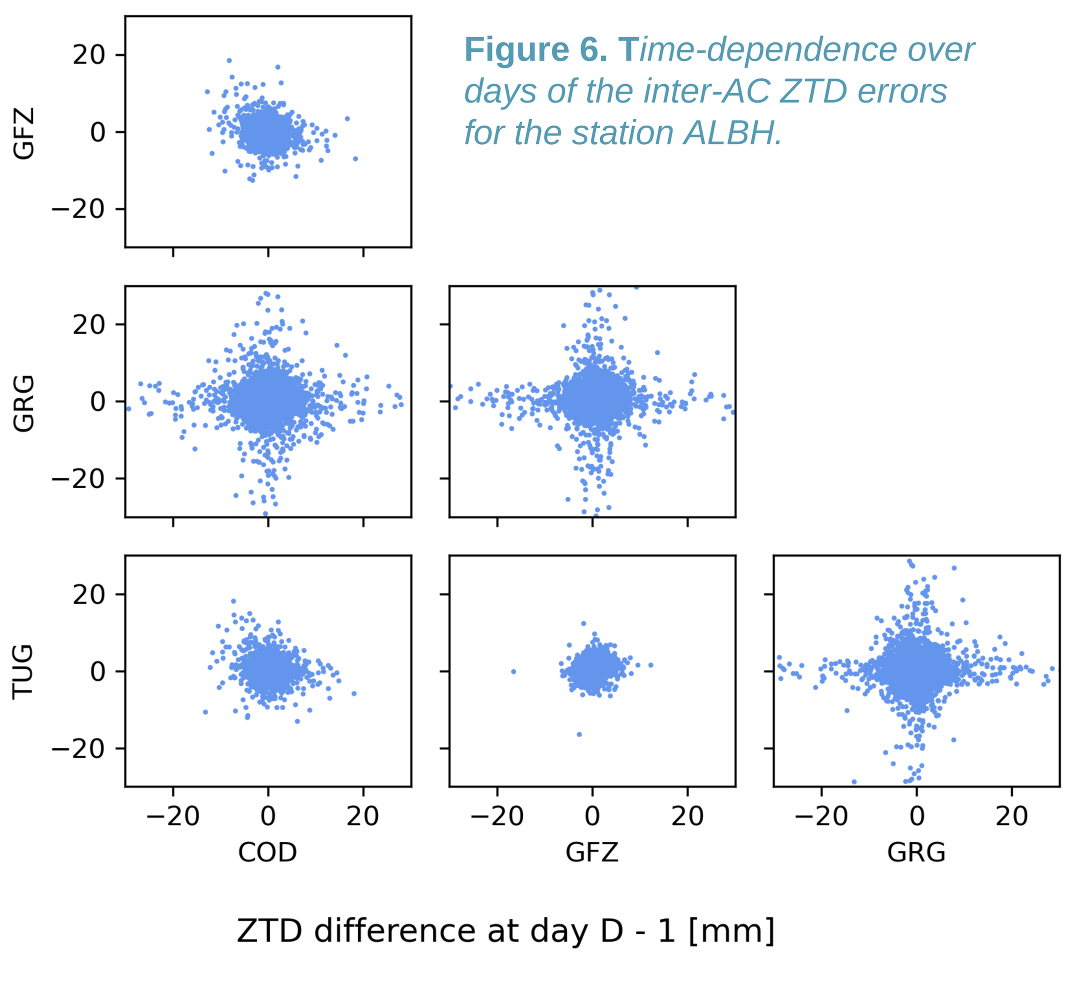


Figure 6. *Time-dependence over days of the inter-AC ZTD errors for the station ALBH.*

<u>General case:</u>

- GRG shows more time-related variations in the differences with the other ACs such as illustrated with ALBH on Figure 6.
- This can be due to the non-constrained ZTD in the GRG processing strategy.

<u>Outlier stations :</u>

- Some stations show a pattern with several clusters such as MKEA on Figure 7.
- These cluster-like patterns are linked to a stall in the ZTD difference time series.

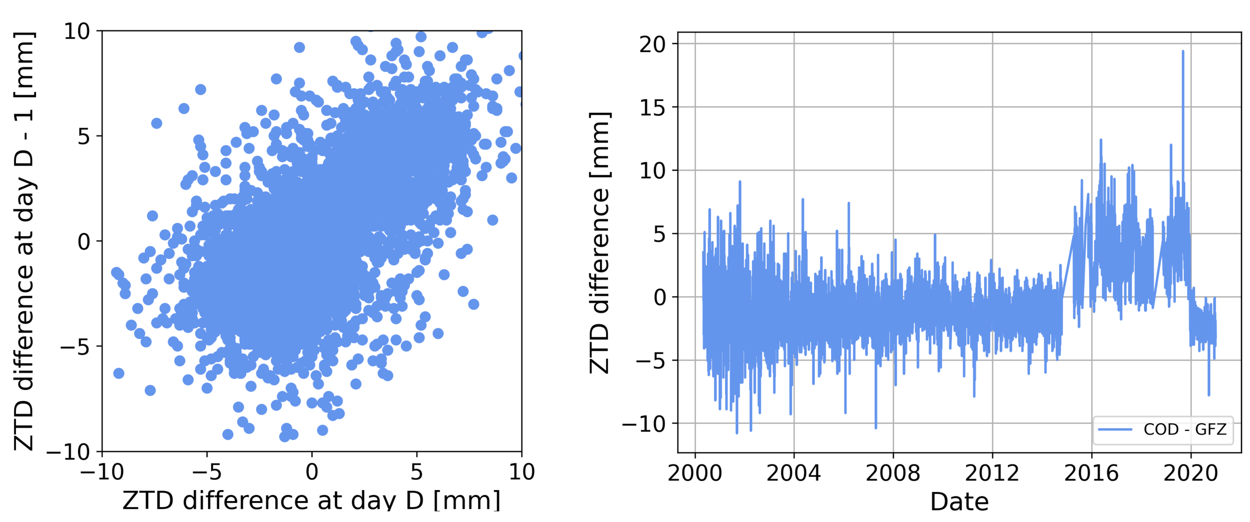


Figure 7. *Double cluster pattern in the MKEA station time-dependence of ZTD difference between TUG and COD (left), and stall in the corresponding time series of the ZTD differences (right).*

Tests of processing parameters effect on ZTD time series

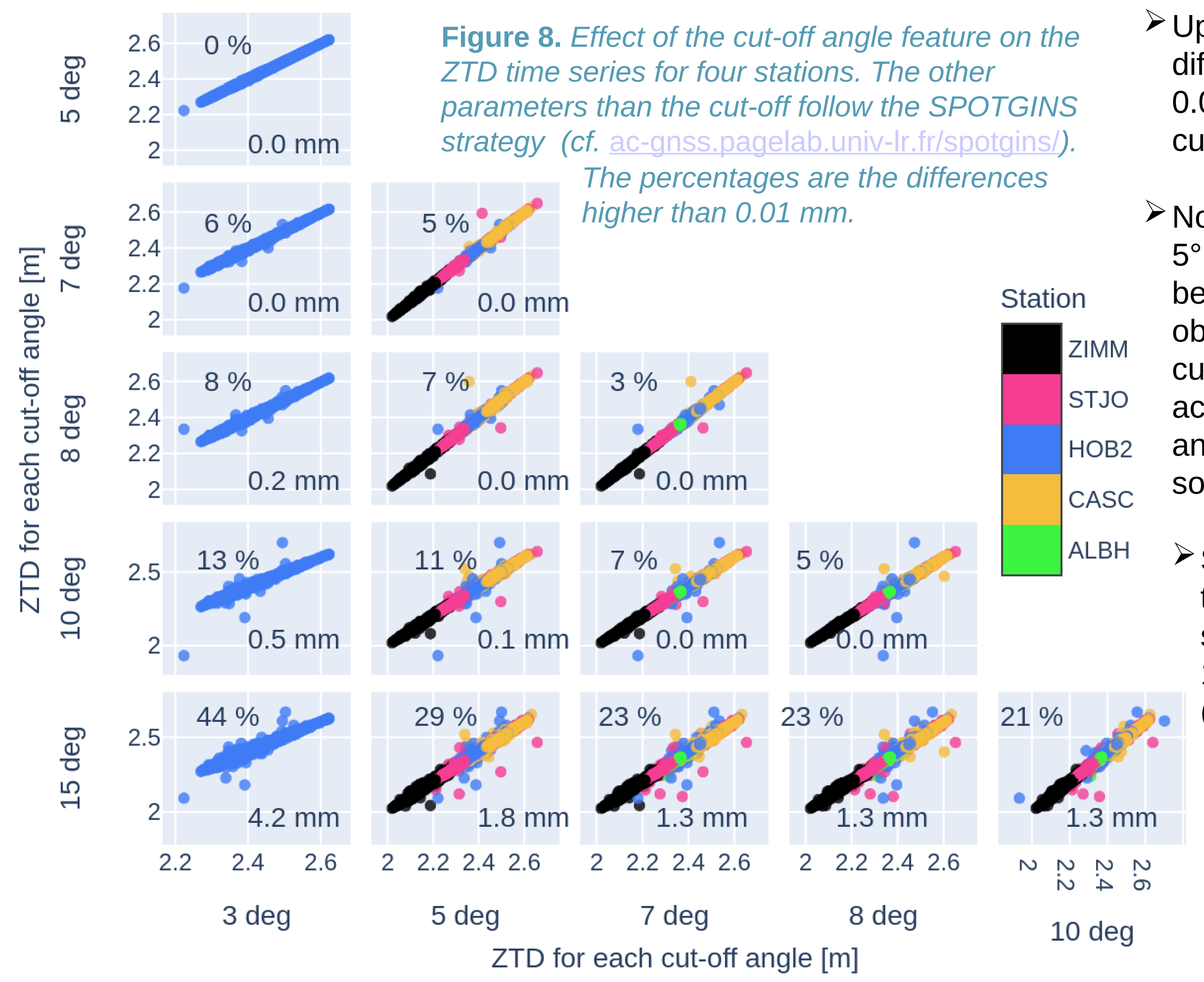
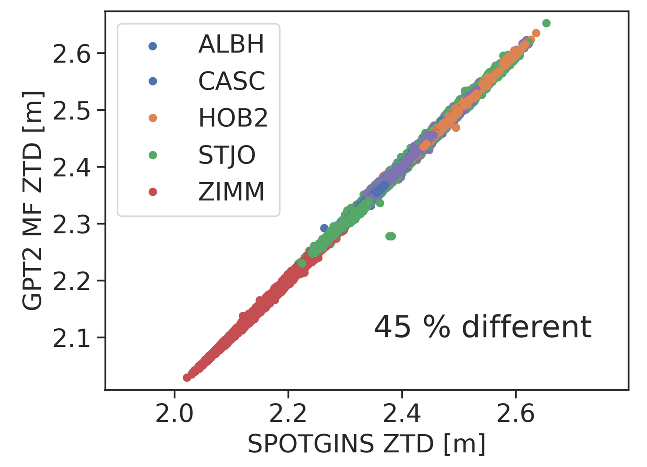


Figure 8. *Effect of the cut-off angle feature on the ZTD time series for four stations. The other parameters than the cut-off follow the SPOTGINS strategy (cf. ac-gnss.pagelab.univ-lr.fr/spotgins/). The percentages are the differences higher than 0.01 mm.*

- Up to 24 % of differences higher than 0.01 mm with 15° of cut-off.
- No difference between 5° and 3° of cut-off because of the observation cut-off in the data acquisition software and the SPOTGINS software.
- Statistical mean of the difference is significant only for 15° of cut-off (millimeter order).



- 45 % of differences higher than 0.01 mm when using GPT2 instead of VMF1.
- Mean of the differences : (0.2 ± 2.0) mm.

Figure 9. *Effect of the mapping function on the ZTD for four stations. The other parameters than the cut-off follow the SPOTGINS strategy (using VMF1). 45 % show differences higher than 0.01 mm.*

Conclusion

- The cut-off angle applied to the elevation and the mapping function has an impact on the resulting ZTD product in a GNSS data processing. High cut-off must probably be avoided. Need to compare to external dataset to know which cut-off is the best.
- They are not sufficient to explain the discrepancies : other features seem to have an impact on the resulting ZTD. Tests on weighting function.
- More stations must be processed to perform a statistical study on the resulting ZTD products and provide a processing configuration guideline for long time ZTD series for climate study.

References and Acknowledgement

- Rebischung et al. (2024). Analysis of the IGS contribution to ITRF2020. Journal of Geodesy, 98(6), 49.
- Jones et al. (2020). Advanced GNSS tropospheric products for monitoring severe weather events and climate. *Springer Cham.*

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