Quality Control using GPS-ZTD time series combination

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Combining different solutions of the atmospheric signal delay from GPS by a Kalman filter can produce a near real time independent quality indicator.

1. Reasoning

When using observations in an application, quality control of observations is essential. GPS Zenith Total Delay (ZTD) observations are estimated by processing time delay observables observed by a network of GPS receivers. Some GPS sites are processed by different analysis centers using different networks, different processing software and (most likely) different processing settings. Combining these solutions can reveal problems in the processing and can provide a quality indicator for each solution.

2. GPS sites

In Fig. A the total of potential available NRT GPS sites in Europe. The number displays is the number of different processing centers that estimate a ZTD for this site.

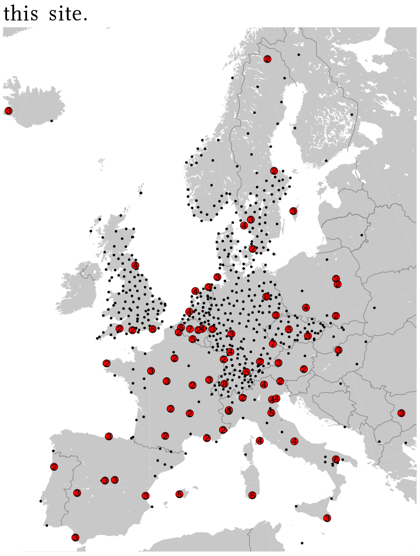

Figure A. *NRT GPS sites in Europe and the number of solutions by different processing centers*

3. Method

Observations $Y_k(t)$ of processing centers $k = 1..K$ at times $t = 1..T$ are used to find a combined solution $Y_C(t)$.

$$Y_k(t) = Y_C(t) + b_k + \epsilon_k(t),$$

where b_k is the bias estimate of the t^{th} time series and $\epsilon_k(t)$ misclosure error. From this a linear functional model can be derived represented by a Gauss-Markov model assuming that the observations noise is random and Gaussian.

The method determines, besides time series biases, time series weights to maintain the consistency of combined solutions applying the principles of variance component estimation. Time series weights determination allows one to take into account possible regional and analysis center dependencies, thus providing homogeneous estimates of ZTD and their standard deviations in near real-time. Both the time series biases and the weights are determined using a Kalman filter. In this case, estimates obtained at the previous step of time series combination are used as the a priori information for the next step.

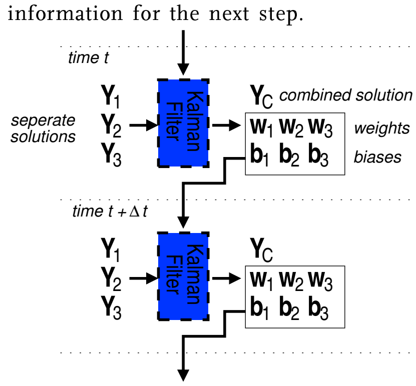

Figure B. *Kalman Filter Scheme*

Fig. B explains the combination method schematically. The method provides a combined troposphere estimates along with their standard deviations based on the different solutions.

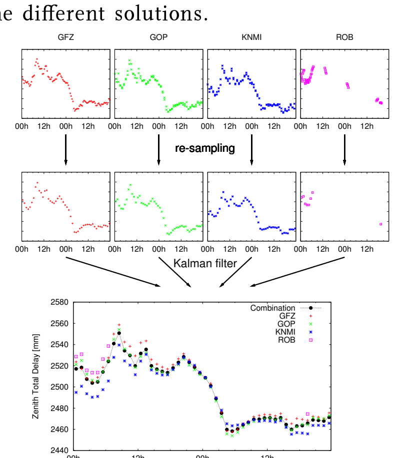

Figure C. *Example of the Kalman Filter*

Fig. C shows a two day example of the GPS ZTD combination filter.

4. Results

For the sites Delft, The Netherlands and Brussel, Belgium the results are shown in Fig. D. and E. respectively.

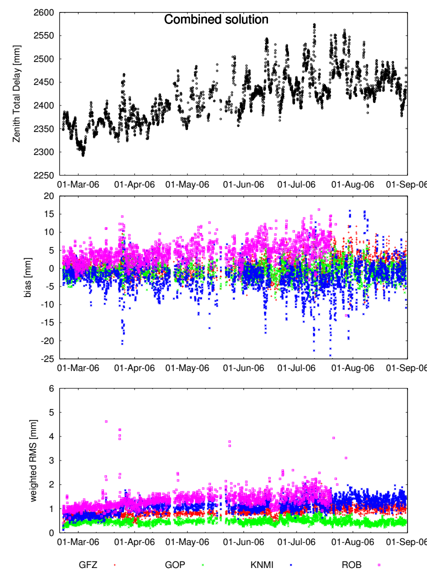

Figure D. *Results for site Delft*

Outliers for Delft are most likely caused by processing failures.

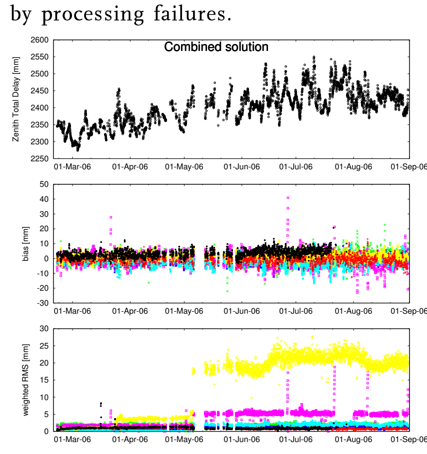

Figure E. *Results for site Brussel*

The change in weighted RMS for LPT is remarkable; notice that this change influences all RMS's.

5. Conclusion

The method described here is capable of detecting possible errors in the GPS ZTD processing. The limitation is that at least three different solution should be available.

References

M. Keshin, Sequential combination of troposphere time series, GPS Solutions, DOI: 10.1007/s10291-006-0028-6.
Internet: http://egvap.dmi.dk

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