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Tropospheric delays derived from Kalman-filtered VLBI observations

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One of the most important error sources in the products of space geodetic techniques is the troposphere. Currently, it is not possible to model the rapid variations in the path delay caused by water vapor with sufficient accuracy, thus it is necessary to estimate these delays in the data analysis. Very long baseline interferometry (VLBI) is well suited to determine wet delays with high accuracy and precision. Compared to GNSS, the analysis does not need to deal with effects related to code biases, multipath, satellite orbit mismodeling, or antenna phase center variations that are inherent in GNSS processing. VLBI data are usually analyzed by estimating geodetic parameters in a least squares adjustment. However, once the VLBI Global Observing System (VGOS) will have become operational, algorithms providing real-time capability, for instance a Kalman filter, should be preferable for data analysis. Even today, certain advantages of such a filter, for example, allowing stochastic modeling of geodetic parameters, warrant its application. The estimation of tropospheric wet delays, in particular, greatly benefits from the stochastic approach of the filter.

In this work we have investigated the benefits of applying a Kalman filter in the VLBI data analysis for the determination of tropospheric parameters. The VLBI datasets considered are the CONT campaigns, which demonstrate state-of-the-art capabilities of the VLBI system. They are unique in following a continuous observation schedule over 15 days and in having data recorded at higher bandwidth than usual. The large amount of observations leads to a very high quality of geodetic products. CONT campaigns are held every three years; we have analyzed all CONT campaigns between 2002 and 2014 for this study.

In our implementation of a Kalman filter in the VLBI software VieVS@GFZ, the zenith wet delays (ZWD) are modeled as random walk processes. We have compared the resulting time series to corresponding ones obtained from other sources (water vapor radiometers, GNSS, ray-traced delays from numerical weather models) and from a classical least squares solution of the VLBI data. Taking the radiometer time series as a reference, the Kalman filter solution showed the smallest root mean square. Due to the high correlation between the ZWD and station coordinates, investigations of the baseline lengths are of great interest in this context as well. Comparing baseline length repeatabilities from the classical least squares fit with those from the Kalman filter, the filter results present a better performance of up to 15%.

To further improve the performance of the ZWD estimation, the noise parameters of the Kalman filter were modeled individually for each station. From ZWD time series at all involved VLBI sites, the power spectral densities of the white noise processes which are driving the random walk processes have been derived. Applying this station-based model results in an improvement of the baseline length repeatabilities of additional 2-3%.