Geophysical Research Abstracts
Vol. 16, EGU2014-423-1, 2014
EGU General Assembly 2014

Applying Kalman filtering to investigate tropospheric effects in VLBI

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Very Long Baseline Interferometry (VLBI) currently provides results, e.g., estimates of the tropospheric delays, with a delay of more than two weeks. In the future, with the coming VLBI2010 Global Observing System (VGOS) and increased usage of electronic data transfer, it is planned that the time between observations and results is decreased. This may, for instance, allow the integration of VLBI-derived tropospheric delays into numerical weather prediction models. Therefore, future VLBI analysis software packages need to be able to process the observational data autonomously in near real-time. For this purpose, we have extended the Vienna VLBI Software (VieVS) by a Kalman filter module. This presentation describes the filter and discusses its application for tropospheric studies.

Instead of estimating zenith wet delays as piece-wise linear functions in a least-squares adjustment, the Kalman filter allows for more sophisticated stochastic modeling. We start with a random walk process to model the time-dependent behavior of the zenith wet delays. Other possible approaches include the stochastic model described by turbulence theory, e.g. the model by Treuhaft and Lanyi (1987). Different variance-covariance matrices of the prediction error, depending on the time of the year and the geographic latitude, have been tested. In winter and closer to the poles, lower variances and covariances are appropriate.

The horizontal variations in tropospheric delays have been investigated by comparing three different strategies: assumption of a horizontally stratified troposphere, using north and south gradients modeled, e.g., as Gauss-Markov processes, and applying a turbulence model assuming correlations between observations in different azimuths.

By conducting Monte-Carlo simulations of current standard VLBI networks and of future VGOS networks, the different tropospheric modeling strategies are investigated. For this purpose, we use the simulator module of VieVS which takes into account the errors due to the atomic clocks at the stations, the troposphere, and white noise processes. The simulated data as well as actual observational data from the two-week CONT11 campaign are analyzed using the Kalman filter, focusing on the tropospheric effects. The results of the different strategies are compared with solutions applying the classical least-squares method.

An advantage of the Kalman filter is the possibility of easily integrating additional external information. It is expected that by including tropospheric delays from GNSS, water vapor radiometers, or ray-traced delays from numerical weather prediction models, the accuracy of the VLBI solution could be improved.