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VLBI TRF determination via Kalman filtering

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The determination of station positions is one of the primary tasks for space geodetic techniques. Station coordinate offsets are usually determined with respect to a linear coordinate model after removing elastic displacements caused by mass redistributions within the Earth's system. In operational VLBI analysis, the coordinate offsets are estimated in a least-squares adjustment as a constant over the duration of a 24-hour VLBI experiment. Terrestrial reference frames (TRF) are usually derived by adjusting the normal equations that contain the 24-hour constant offsets in order to estimate a linear model, possibly including breaks, for the station positions. We have created a VLBI TRF solution without the assumption of negligible subdaily motion and of linear behavior on longer time scales by applying a Kalman filter.

As a preparation for the upcoming VLBI Global Observing System (VGOS), which aims for continuous observations that are available in real-time, a Kalman filter has been implemented into the VLBI software VieVS@GFZ. In addition to the real-time capability, the filter offers the possibility of stochastically modeling the parameters of interest.

For station coordinates, changes in a subdaily time frame occur, for instance, from un- or mismodeled geophysical effects. The models for tidal and non-tidal ocean, atmosphere, and hydrology loading are known to have deficiencies and inconsistencies which propagate into the estimated station coordinates. The stochastic model of the Kalman filter can be adapted to take these subdaily effects into account.
Comparing the resulting station coordinate time series with daily values from a least squares fit, we have investigated to what extent and in which regions the loading models currently have deficiencies.

Due to the high correlation between station height and tropospheric delays, it is possible that errors in one group of parameters are partly absorbed by the other group. To detect problems with correlations and to avoid geophysical misinterpretation of the station coordinate variations, we have included external data from water vapor radiometers and GNSS in our comparisons.

Another cause for non-linear station motions are earthquakes and other episodic events that result in an offset of up to a few meters in the station coordinate time series. The non-linear post-seismic behavior can last from a few months up to several years and is another challenge for the creation of TRF. By using a Kalman filter, we have the possibility to dynamically adjust the stochastic model, loosening it in case of earthquakes, post-seismic activity, and comparable events and tightening the movement during quiet times.

By analyzing more than 30 years of VLBI observations with the Kalman filter we have created a TRF-like product consisting of subdaily station coordinates. The TRF stability, which is otherwise gained by enforcing a linear model, is here realized by appropriate stochastic modeling. In addition to the advantages related to the modeling of non-linear station motion mentioned above, it has the great benefit of being easily updated when new observational data becomes available, in the future possibly in near real-time.