IVS Memorandum 2006-010v03

7 September 2006

“V2C Simulations at IGG Vienna”

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Date: 07 September 2006
Memo: V2C Simulations at IGG Vienna
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Introduction

Based on the Memo 2006-013v01 Simulations of Wet Zenith Delays and Clocks we generate simulated observations (group delays) for various schedules. These group delays o-c (observed minus computed) are built as the sum of the wet zenith delay times wet mapping function, the clock and a white noise which simulates the observation errors.

$$o - c = \left(wzd_2 \cdot mfw_2(e) + clock_2 + wn_2\right) - \left(wzd_1 \cdot mfw_1(e) + clock_1 + wn_1\right) \qquad (1)$$

Analysis with OCCAM: Gauß-Markov vs. Kalman-filter

Due to the high density of observations and the larger number of parameters to be estimated in the simulated sessions, we could not solve the normal equation system of the Gauß-Markov model as implemented in OCCAM in reasonable time. Thus, we decided to change the analysis from the classical Gauß-Markov algorithm to the Kalman-filter which is also implemented in OCCAM.

To compare the results of the analysis between Kalman-Filter and the Classical Gauß-Markov least squares adjustment we used exactly the same simulated group delays (eq. 1). A schedule with fewer observations was used to be able to run the Gauß-Markov least squares estimation without problems. This schedule contains the same 16 stations as shown in figure 2 with 932 scans which comes up to 9678 observations. The observation density is 11 scans/hour/station and on the average we have one observation every 93 sec., the max time without any observation is 7min and 20sec.
Figure 1 shows the baseline length repeatability for both analysis strategies (from 25 iterations). The Kalman-filter gives a slightly better repeatability than the classical Gauß-Markov least squares adjustment. With the classical Gauß-Markov least squares adjustment we set the resolution of wet zenith delay and clock parameters to 30 minutes, which might be the reason for the difference between the two analysis strategies.

The Kalman-filter seems to be advantageous for simulations, because the resolution of the wet zenith delays and clocks only depends on the observation density and does not have to be adjusted for each schedule as it is the case with the Gauß-Markov model.

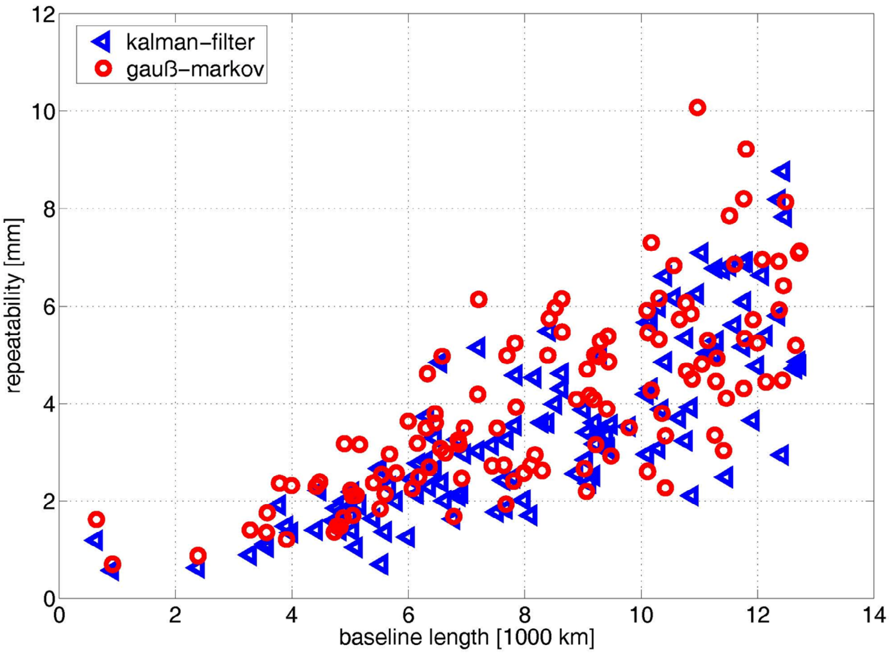

Figure 1: Baseline length repeatability for the Kalman filter (blue triangles) and the classical Gauß-Markov least squares adjustment (red circles) (25 iterations).

Kalman-filter simulation schedules

In the following we use a schedule that achieves about 45 scans per hour per station (created by Toni Searle and Bill Petrachenko). To get this high density the schedule program SKED was tricked by using a number of identical antennas with the same size as Algonquin but with faster slewing rates. The antenna specification was set as follows: azimuth max slewing rate of 18 deg/s, azimuth max acceleration of 3.6 deg/s², elevation max slewing rate of 4.5 deg/s and elevation max acceleration of 0.9 deg/s², and a data rate of 48 Gb/s.
The station distribution can be seen in Figure 2, in total 16 stations are included in the schedule. The minimum scan length was 5 sec and the maximum scan length 60 sec. The source catalogue included 50 sources. SKED ended up with 2737 scans which correspond to 57595 observations for 120 baselines.

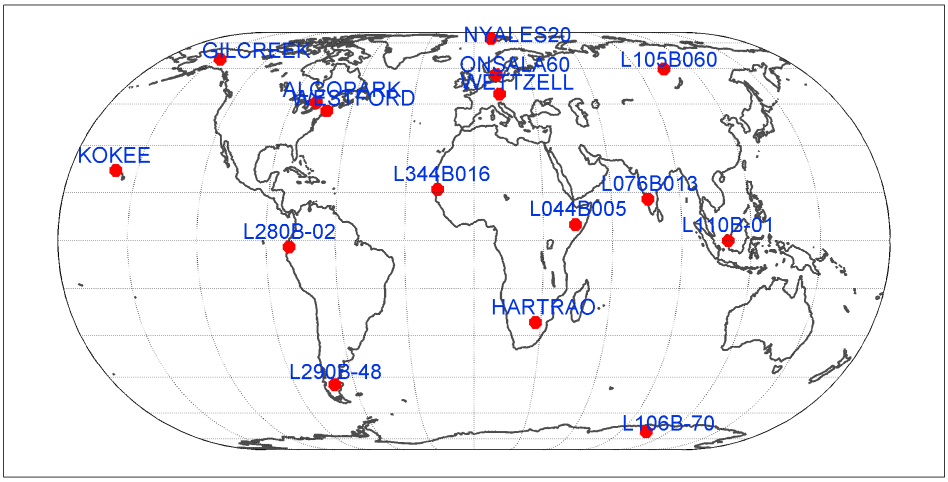

Figure 2: Station distribution: In addition to 8 existing locations, 8 new sites are used.

The Monte Carlo simulator was implemented in OCCAM and creates random walk values for the wet zenith delays and clocks and white noise for each station at each epoch as shown in the Memo 2006-013v01.

The wet zenith delays and clocks are modeled as random walks with different power spectrum densities (PSD) (see table 1). The Allan Standard Deviation (ASD) of the clocks is converted to the PSD of a random walk ignoring the integrated random walk part.

wzd	0.1 [psec^2/sec]	0.7 [psec^2/sec]	
clocks	$2 \cdot 10^{-15}$@15min (ASD) 0.0036 [psec^2/sec] (PSD)	$1 \cdot 10^{-14}$@50min (ASD) 0.3 [psec^2/sec] (PSD)	
white noise	4 psec	8 psec	16 psec

The analysis was done with the Kalman-filter estimating wet zenith delays and clocks at every observation epoch. Figure 3 shows the baseline length repeatability for 3 different levels of white noise: 4, 8 and, 16 psec. The clocks were simulated to agree with an ASD of 2e-15@15min and the wet zenith delays are based on a PSD of 0.1 psec**2/sec. Between the solutions with 4 and 8 psec white noise (which correspond to the observation error), no big differences can be detected. On the other hand the degradation with 16 psec white noise is rather significant. This means that the influence of wet zenith delays with a PSD of 0.1 psec**2/sec and a clocks with and ASD of 2*10-15@15min for a schedule like this so large that there is hardly any improvement with a '4 psec antenna' compared to an '8 psec antenna'.

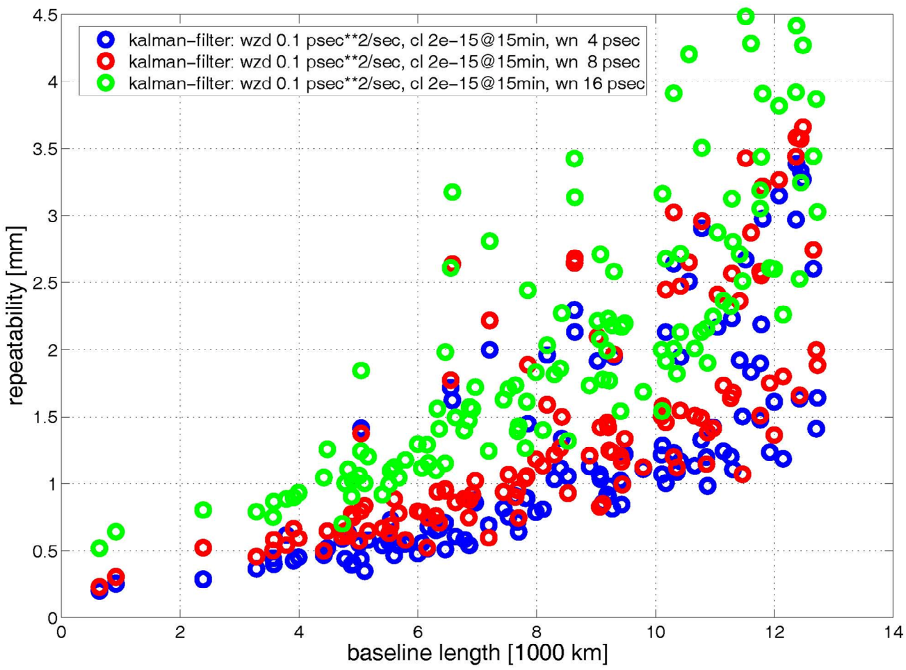

Figure 3: Baseline length repeatability (25 iterations) for 3 different levels of white noise: 4 (blue), 8 (red) and, 16 psec (green). Clocks are simulated with an ASD of 2e-15@15min and wet zenith delays are simulated as random walks with a PSD of 0.1 psec**2/sec.

The same analysis was done with wet zenith delays with a PSD of 0.7 psec**2/sec. The result (figure 4) shows that the PSD of the wet zenith delays dominates the baseline length repeatability and the influence of the white noise decreases. With this combination an antenna with an accuracy of 4 psec will give nearly the same results as a '16 psec antenna'. Thus, schedules with higher observation densities need to be simulated to see whether baseline length repeatabilities improve with more observations.

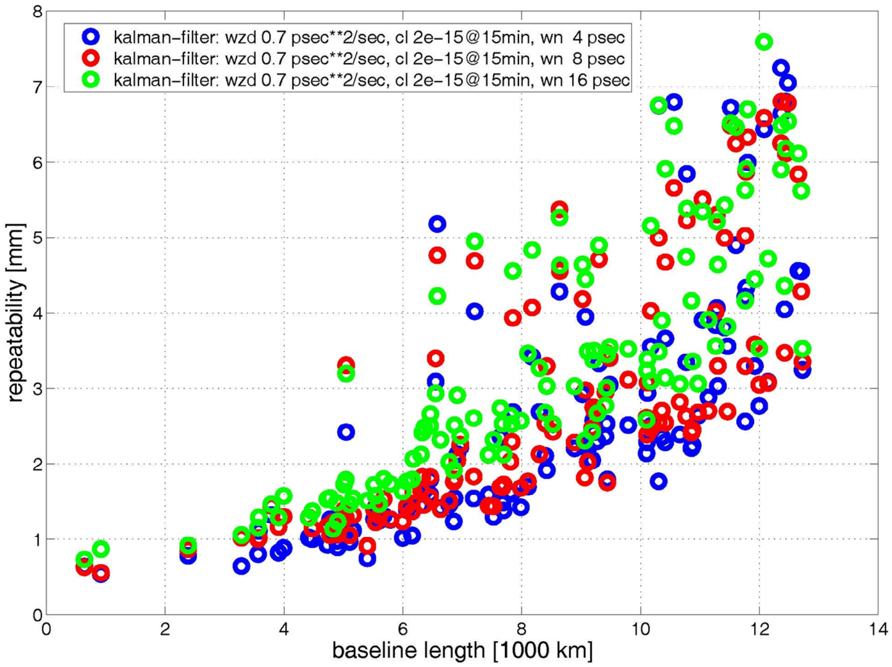

Figure 4: Baseline length repeatability for 3 different levels of white noise: 4 (blue), 8 (red) and, 16 psec (green). Clocks are simulated to have an ASD of 2e-15@15min and wet zenith delays have a PSD of 0.7 psec**2/sec.

The effect we get if we change the ASD of the clock to 1e-14@50min can be seen in figure 5. We can clearly see the 3 different levels of noise. Thus the baseline length repeatability is not dominated by the ASD of the clocks.

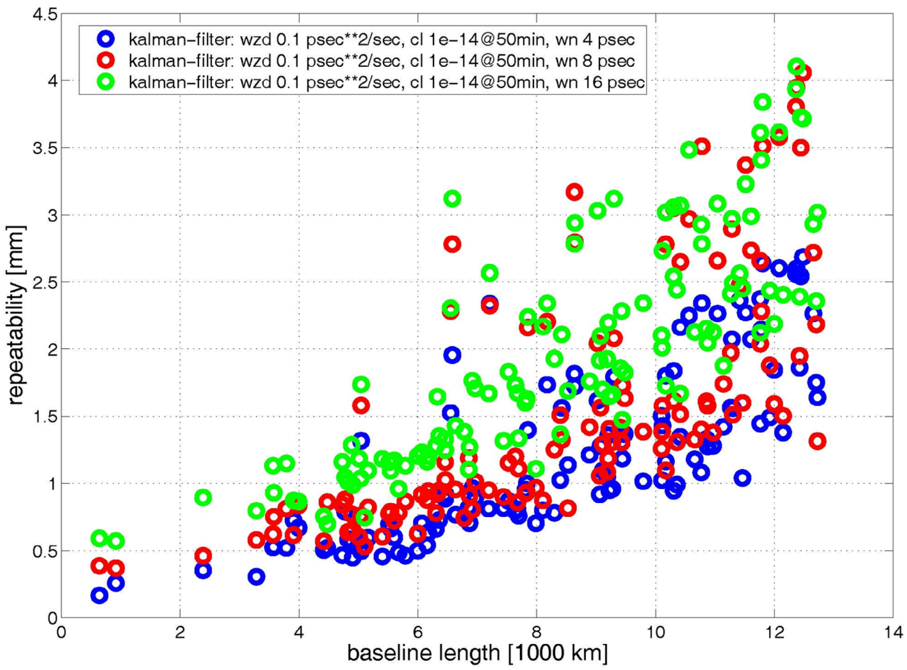

Figure 5: Baseline length repeatability for 3 different levels of white noise: 4 (blue), 8 (red) and, 16 psec (green). Clocks are simulated to have an ASD of 1e-14@50min and wet zenith delays have a PSD of 0.1 psec**2/sec.

To compare the different ASD of the clocks, figure 6 shows two different levels of noise, 4 and 16 psec and the two ASD for the clocks, 2e-15@15min and 1e-14@50min. The PSD of the wet zenith delay was set to 0.1 psec**2/sec.

In general very small differences for the baseline length repeatability can be seen by changing the ASD from 2e-15@15min to 1e-14@50min. For baselines with the station L106B-70 (2703 observations compared to Wettzell 9754 observations in the schedule) degradation in baseline length repeatability for different ASD can be seen. This is marked in figure 6 for the 16 psec level of noise. This effect can be reduced by a schedule with homogeneous observation density.

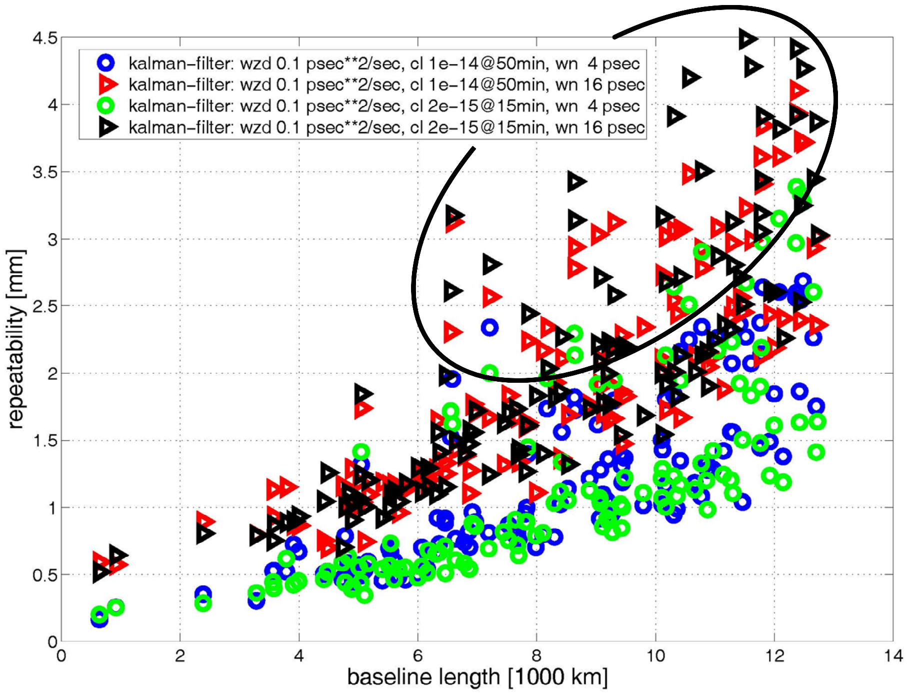

Figure 6: Baseline length repeatability for 2 different levels of white noise: 4 (circles) and 16 (triangles). Clocks are simulated to have an ASD of 1e-14@50min (blue/red) and 2e-15@15min (green/black), the wet zenith delays have a PSD of 0.1 psec**2/sec.

Next steps

- Use different variances station-dependent clocks and wet zenith delays.
- Use different schedules (density, stations, sources)
- Check the improvement with two telescopes at one site.