# IVS Memorandum 2007-004v01

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# "Comparison of OCCAM LSM & OCCAM Kalman Filter & CALC/SOLVE"

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Memo: Comparison of OCCAM LSM & OCCAM Kalman Filter & CALC/SOLVE
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# 1. Introduction

The main task of this memo is the comparison between the two VLBI analysis software packages CALC/SOLVE and OCCAM. In the case of OCCAM, two adjustment procedures are compared: the 'classical' least-squares method (LSM) and the Kalman Filter (KF).

Because OCCAM LSM has limitations in terms of size of design matrix, a 12 hour session was used for the comparison. We also compared results of OCCAM (KF) and SOLVE for a 16 station schedule (Stat16_4p5_2p1_D0.skd) observing over a 25-day period for which we also used turbulent delays. This is discussed in the last section.

The vector (o-c) (observed minus computed) was set to the sum of three stochastic processes:

$$o - c = \left(wzd_2 \cdot mfw_2(e) + clock_2\right) - \left(wzd_1 \cdot mfw_1(e) + clock_1\right) + wn_{bsl}$$

The wet Niell Mapping Function NMF was used to set up (o-c), and it was also used as partial derivative to estimate the wzd in the adjustment.

All simulated data files (wzd, clocks, and white noise) and results of the software packages can be found at http://mars.hg.tuwien.ac.at/~vlbi2010/stat16_6_2p1D_h/.

Table 1. Network stations. The order is taken from the sked file.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1. NYALES20 | 2. WETTZELL | 3. HARTRAO | 4. BAN2 | 5. BADARY | 6. TSUKUB32 | 7. HOBART26 | 8. KOKEE |
| 9. TAHITI | 10. GILCREEK | 11. TIGOCONC | 12. WESTFORD | 13. FORTLEZA | 14. KWJ1 | 15. MAS1 | 16. KERG |

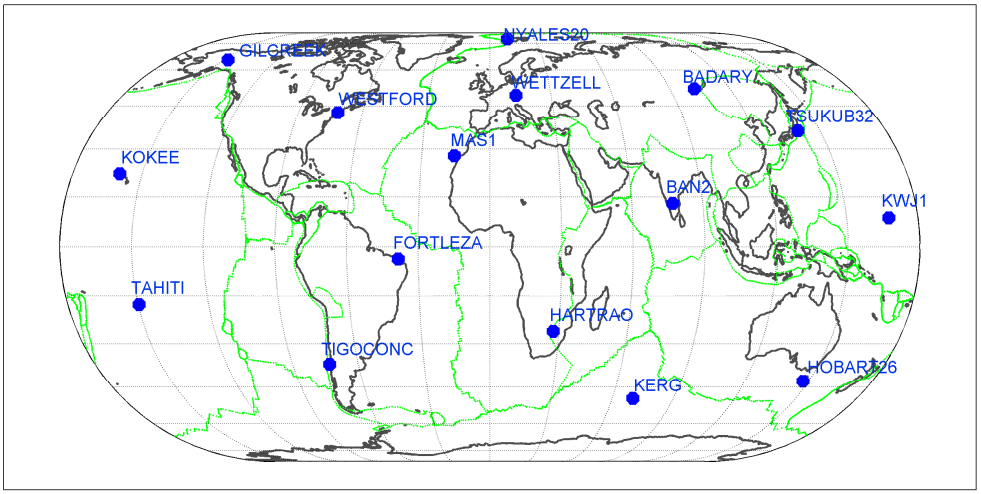


Figure 1. 16 station network

# 2. Simulated observation

## 2.1 Clocks

An input file (A_2p1D_h_clocks.dat) with clock values at each scan for each station based on the schedule stat16_6_2p1D_12h.skd was generated. The clock values are simulated as the sum of a random walk and an integrated random walk, corresponding to an Allan Standard deviation of 2e-15@15min. Units are [ns] and the station order in the clock file corresponds to the order in the sked file (Table 1). (The first column is modified Julian date.)

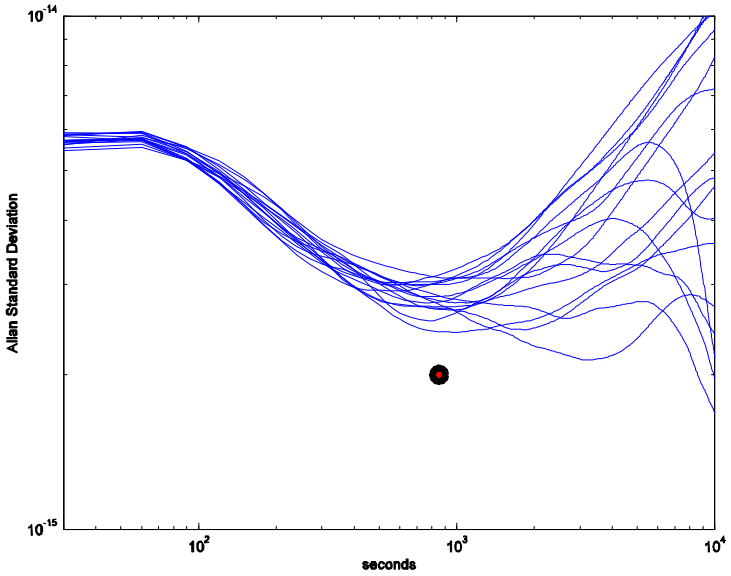


Figure 2. Allan Standard Deviation of the simulated clocks. The dot shows 2e-15@15min.

## 2.2 Wet Zenith delay

### Turbulence files

The turbulence files (Nilsson T, Haas R.) include a wet zenith delay value for each epoch and station. The values given in file A_2p1D_h_turb.dat are wet zenith delays in [mm]. The station order in the turbulence files is **alphabetic!** The first column is modified Julian date.

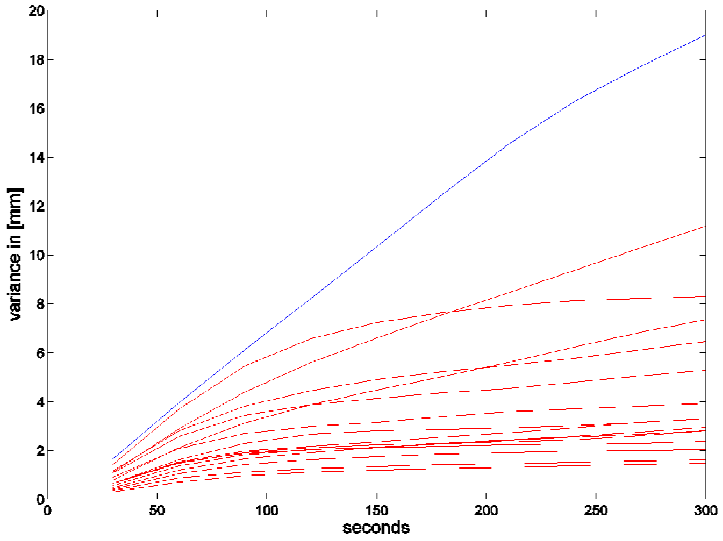

Figure 3. Structure function of the wet zenith delays at each station (red) and the structure function of a random walk with a PSD of 0.5 psec**2/sec (blue).

### 2.3 White noise

The white noise was simulated for each observation (baseline). The white noise has a standard deviation of 4 [psec] and is given in the file A_6_2p1D_h_wn.dat in [psec].

## 3 Comparison CALC/SOLVE & OCCAM

For CALC/SOLVE and OCCAM LSM, parameterization as similar as possible is used:

- NNR/NNT for a priori station coordinates, ICRF fixed.
- 5 EOP offsets (X, Y, UT1, Psi, Eps) for the 12 hour session
- 20 min piecewise linear for wet zenith delays with 15 mm/hour constraints
- quadratic function plus 60 min piecewise linear for clocks
  with 54 mm/hour constraints (OCCAM LSM) and 11 mm/hour (SOLVE)
- 6 hour piecewise linear for gradients with 2 mm/day constraints, 0.5 mm on gradient offset

Because the vector (o-c) is set to the sum of stochastic parameters, the expectation value for the unknowns (adjustments) is zero.

Formal errors are multiplied with the square root of $\chi^2$.

## 3.1 Earth orientation parameters

Table 2. Earth orientation parameters.

| | xp [uas] | yp [uas] | dut1 [us] | psi [uas] | eps [uas] |
|---|---|---|---|---|---|
| LSM | -0.1 ± 3.4 | -9.2 ± 3.5 | 0.7 ± 0.2 | 34.9 ± 7.9 | 12.6 ± 3.3 |
| SOLVE | -0.5 ± 3.9 | -12.6 ± 4.1 | 0.9 ± 0.2 | 37.0 ± 8.1 | 11.0 ± 3.3 |

## 3.2 Station heights

The sigmas from SOLVE of the station heights are about 0.5 mm, from LSM about 0.7 mm, from the Kalman Filter about 0.5 mm

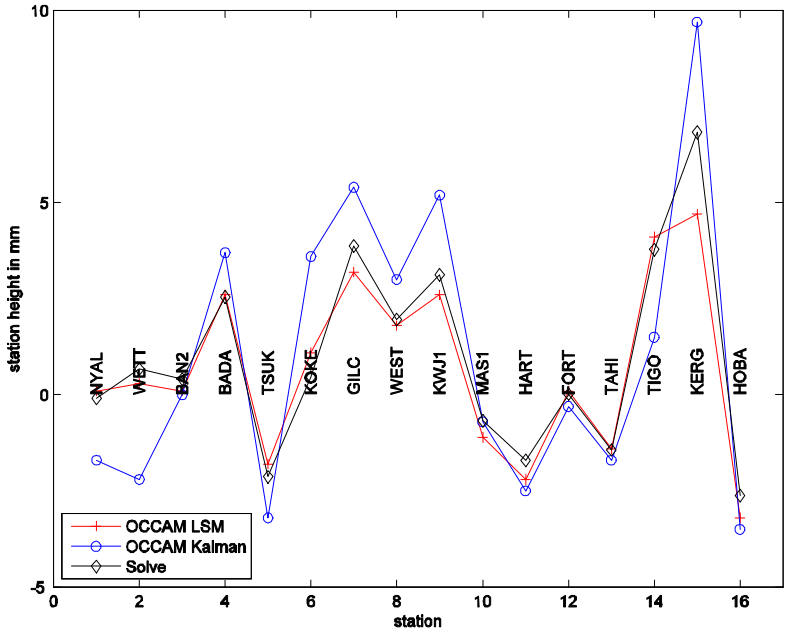


Figure 4. Adjustments for the station heights in mm.

## 3.3 Baseline lengths

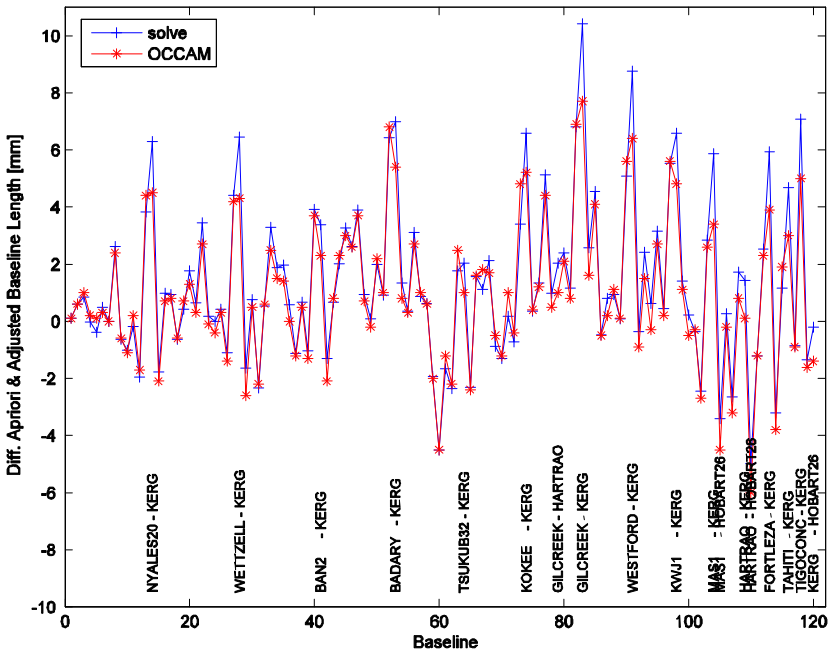


Figure 5. Adjustments for the baseline lengths in mm.

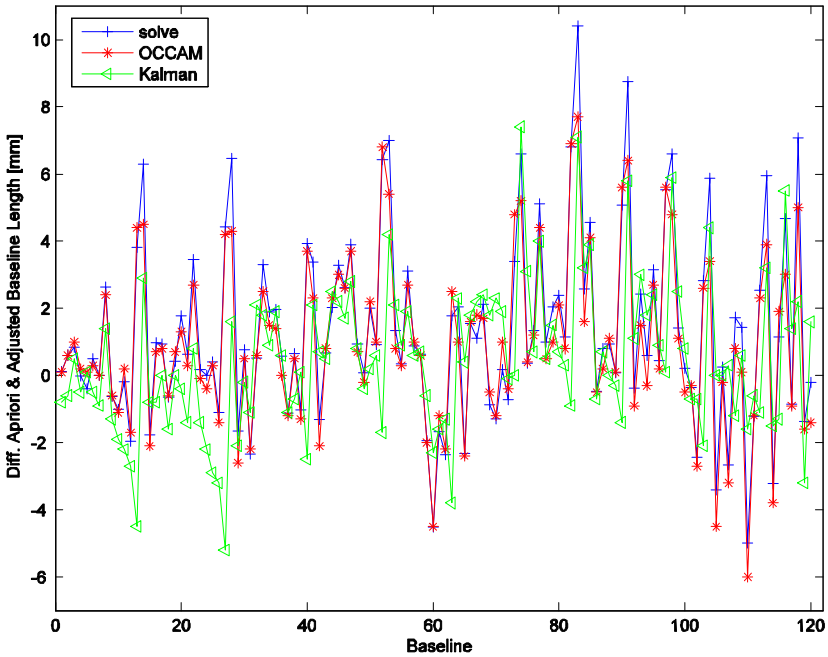


Figure 6. Adjustments for the baseline length including the Kalman Filter solution. The discrepant SOLVE baselines involve the site KERG.

### 3.4 Wet zenith delays

The sigmas from SOLVE of the wet zenith delays are about 0.3 mm from LSM about 0.6 mm.

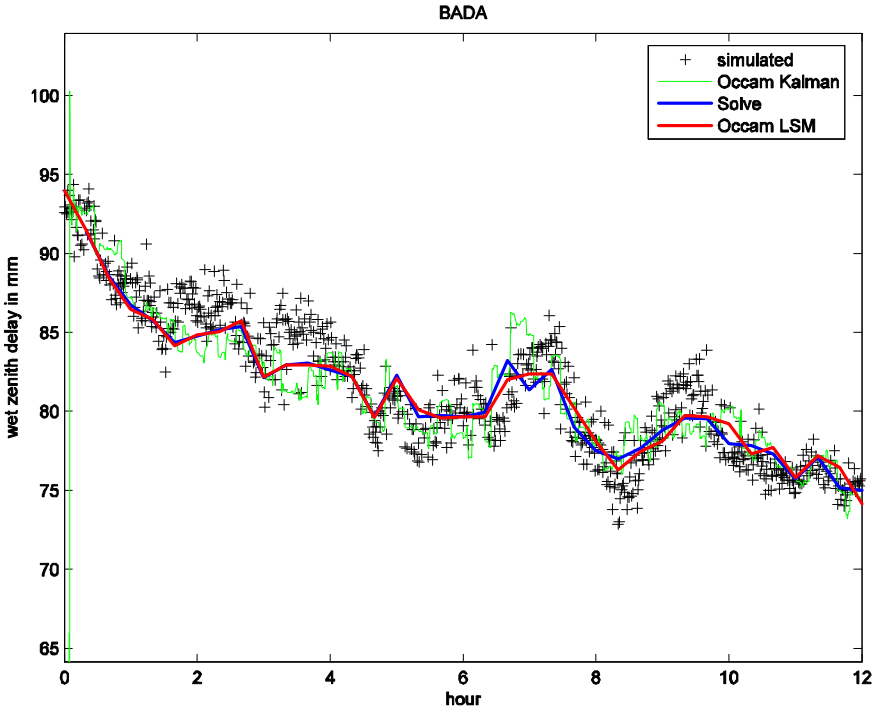


Figure 7. Estimated wet zenith delays for station BADA

## 4 Baseline length repeatabilities

The baseline repeatabilities have been calculated for 25 identical 24 hour sessions of the same schedule and are shown for the CALC/SOLVE and the OCCAM Kalman solution. The schedule stat16_4p5_2p1D0 was modeled with the turbulence model, a white noise of 4 psec/baseline and clocks with an ASD of 2e-15@15min. The two different software packages show even a better agreement if the interval of 6 min for estimation of the wzd in the CALC/SOLVE solution is chosen instead of 20 min

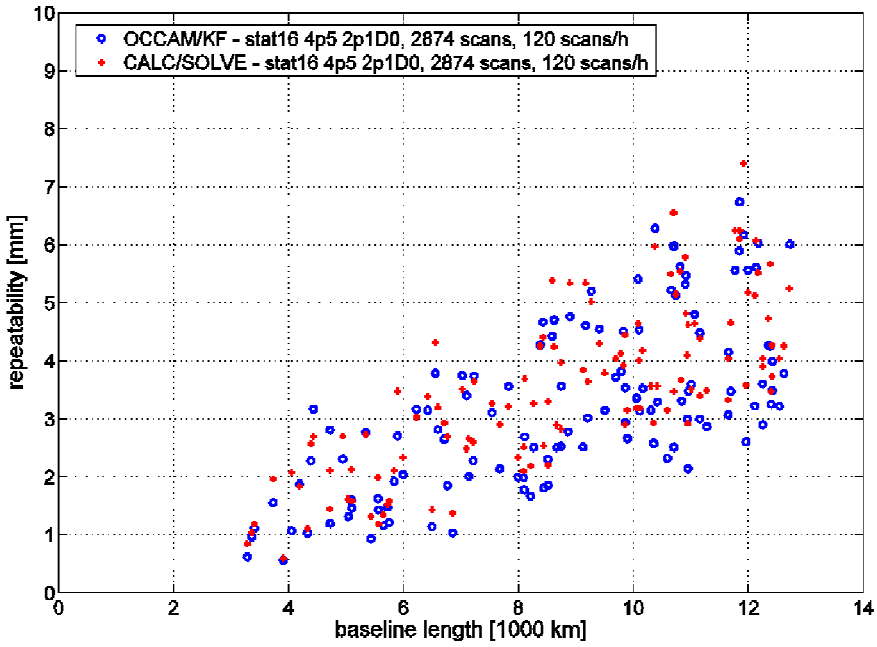


Figure 8. Baseline length repeatabilities for the schedule stat16_4p5_2p1D0 analyzed with CALC/SOLVE and OCCAM/KF.

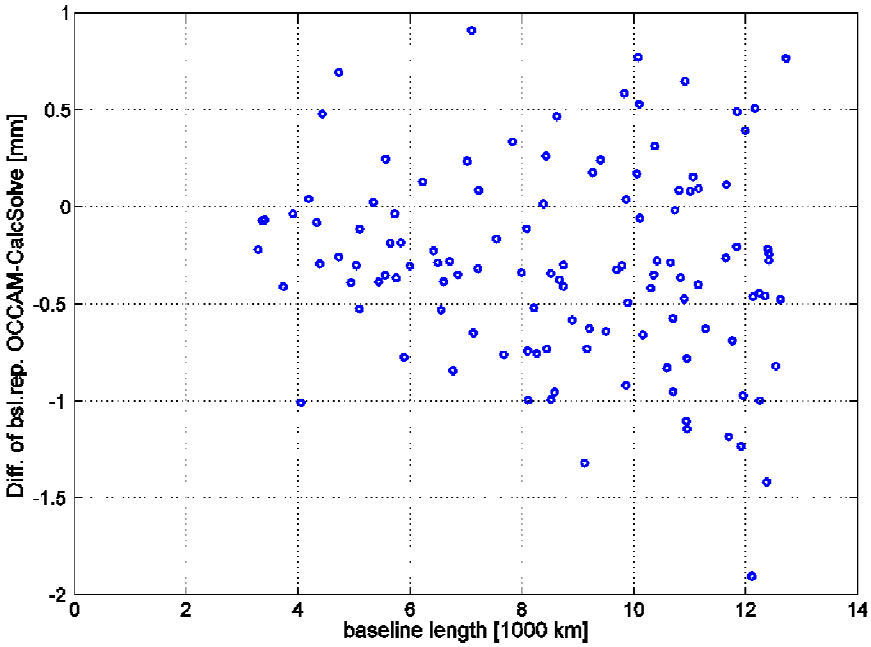


Figure 9. Differences between OCCAM/KF and CALC/SOLVE estimated baseline length repeatabilities for the schedule stat16_4p5_2p1D.

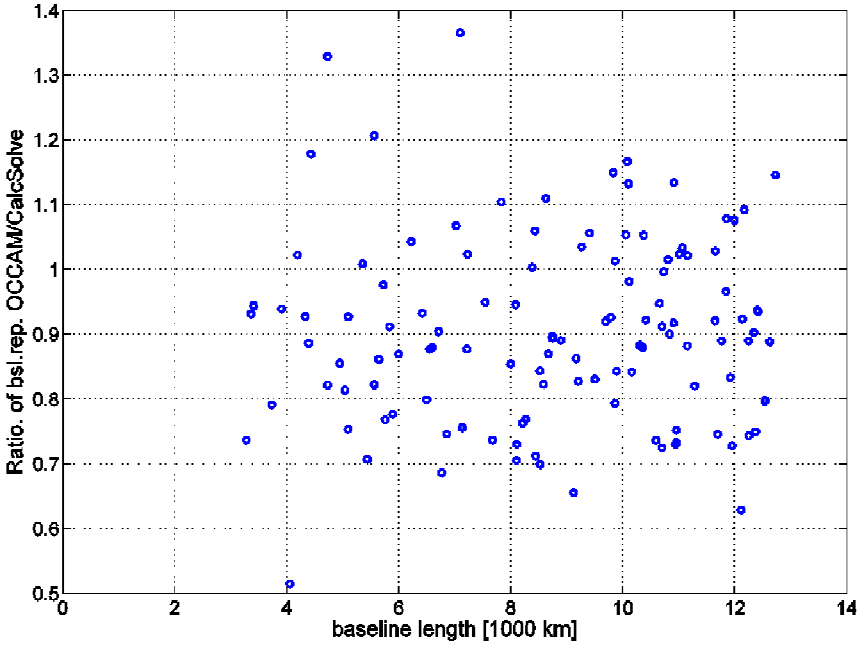


Figure 10. Ratio OCCAM/KF and CALC/SOLVE estimated baseline length repeatabilities for the schedule stat16_4p5_2p1D0.