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OCCAM v.6.0 Software for VLBI Data Analysis

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Abstract

The OCCAM VLBI software package, originally developed in the beginning of the 80s, has been maintained by different scientists from different countries and agencies. The current version 6.0 of OCCAM is a powerful tool with new models and strategies to accomplish several tasks in astrometry and geodesy. For example, new mapping functions based on numerical weather models have been implemented in the software. Three options for the adjustment (least squares collocation, least squares method and Kalman Filtering) are available. A short description of the strategies is presented as well as results of their application.

1. Introduction

OCCAM is a transportable, freely distributed software package for VLBI data analysis which is based on NGS cards. The version 6.0 is an enhancement of the previous OCCAM version 5.0 [11]. Currently, it is in use on different platforms (PC, HP, LINUX). All codes are generally available for check and update.

2. Data Reduction

All reductions correspond to the IERS Conventions 2003 except the IAU 2000 recommendations, which have not been implemented yet.

- Three mapping functions (NMF [5], VMF [1], IMF [6]) are available for data analysis.
- Positions and velocities of the Sun, Earth and Moon are calculated using new ephemerides DE405/LE405.
- Nutation models IAU1980 and MHB2000 are available optionally.
- Subdiurnal EOP variations can be calculated using the Eanes [2] or Gipson [4] models.
- Atmospheric loading corrections are used from Petrov and Boy ([7]).
- The antenna thermal deformations are computed as described by the Skurikhina model [8], which is developed from the official IERS (2000) model [14].
- OCCAM 6.0 supports three options for the calculation of the geometric delay (IERS 1992 [12], IERS 1996 [13] and the IAU 1997 models).

3. Adjustment

The adjustment can be carried out using three different methods: Kalman Filter (KF), least squares method (LSM) and least-squares collocation method (LSCM):

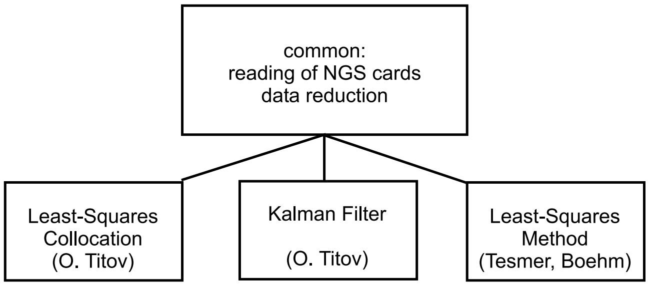

Figure 1. After the data reduction, there are three different options for the adustment strategy: O. Titov takes care of the Kalman Filter and the least-squares collocation method, J. Boehm and V. Tesmer are in charge of the classical least-squares method.

- The Kalman Filter option is used for operational EOP service. All five EOP and the first derivatives of the pole components and UT1-UTC are estimated on a daily basis as well as VLBI station coordinates. To solve the system of normal equations for daily TRF estimates, NNT and NNR constraints are applied. A random walk model is used for the stochastic parameters clock offset and wet delay. Clock rates and wet gradients are treated as constant parameters, but sometimes, the clock rate is treated as stochastic in case of the maser instabilities.
- The LSM treats the tropospheric parameters (zenith delay and horizontal gradients), as well as the clocks as piece-wise linear functions on segments from 20 minutes to 4 hours. This option is currently used to evaluate the EOP and the TRF in a global sense, but not yet operationally.
- The LSCM allows a global adjustment of the VLBI data with which a consistent solution of the CRF, TRF and EOP can be obtained. All parameters are subdivided into three groups: global (constant for the full period of observations), daily or 'arc' (constant for 24-hour session) and stochastic (variable from scan to scan). The wet delays and gradients and clock offsets are treated here as stochastic parameters with an apriori mathematical expectation and a covariance matrix. A three-group parametrical model is used as described by [9]. The covariance functions for the clock offsets and the wet delays are calculated in accordance with [10]. We used WVR data by Haas (see [3]) to build up the covariance function for the wet gradients. Having the a priori covariance, the full covariance matrix is calculated for each VLBI session. It takes into account the correlations between observables inside the 24-hour session. The algorithm also permits estimation of all of the stochastic parameters with a time resolution corresponding to the rate of VLBI data performance (5-10 minutes). Unfortunately, the time for the full matrix inversion increases in proportion N^3 (where N is the number of observations), wherefore the LSCM requires too much computing time and RAM memory.

4. OCCAM 6.0 - Results

Using the LSCM option, a CRF solution can be built up. The catalogue AUS2003b has recently been submitted to the IVS database. It includes updated coordinates for 682 radiosources from 2985 sessions over a 24-year period (1980-2003). The median accuracy of the catalogue is ~0.2 mas. The weighted rms of the solution is 22 psec. All the radiosource positions are treated as global parameters, therefore, the approach needs to be updated to take into account apparent proper motion caused by different effects.

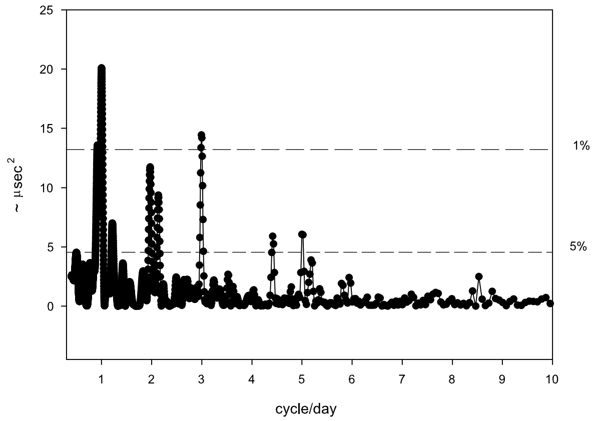

Figure 2. PSD of the UT1-UTC variations (CONT02). Model by Eanes [2] has been extracted.

A time series of the station coordinates is also available from the LSCM solution. An additional least squares adjustment gives station coordinates and velocities for a selected reference epoch. The velocities of 52 VLBI sites have been estimated in frame of the AUS2003b solution. The results are in close agreement with those of other VLBI and GPS studies. Nonetheless, some non-linear effects (mostly of seasonal character) in the station position time series with amplitude up to 1 cm have been found.

Table 1. The list of signal significant at the 5% level in the UT1-UTC variation spectrum from CONT02 campaign

Frequency of signal (cycle/day)	**Period (day)**	**Relation of the amplitude to the 5% criteria level**
5.0	0.2	2.1
4.425	0.226	2.0
3.0	0.334	3.1
2.137	0.468	2.5
1.969	0.508	2.8
1.217	0.822	2.2
1.0	1.0	3.7
0.919	1.088	3.0
0.5	2.0	1.8

LSCM-estimated Earth orientation parameters with high time resolution were analysed to compute spectra of the variations with periods less than 24 hours. Fig. 2 shows the spectrum of UT1-UTC variations from the two-week CONT02 VLBI campaign, which provides 15 days of continuous VLBI observations of eight participating stations. As the Eanes model (2000) [2] has been removed from the time series, the plot present the deviations from the model. Some signals with frequencies around 1 and 3 cycles/day are significant on the 1% level; more signals are significant on the 5% level (see Table 1). Some of the signals are not predicted by any model. Therefore, confirmation of them from analysis of independent time series is essential. An interpretation of the signals still has to be done.

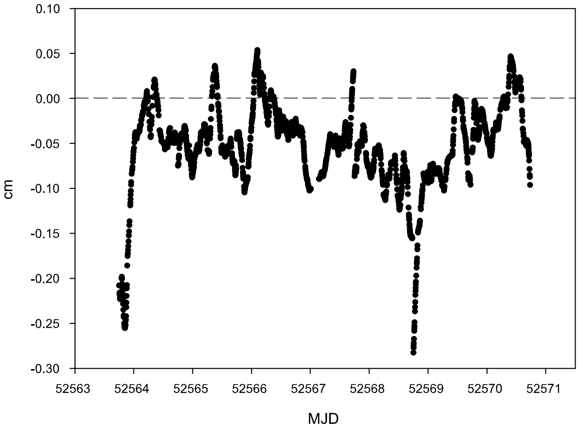

Figure 3. Variations of the north troposphere gradient for the Onsala VLBI site from the CONT02 campaign.

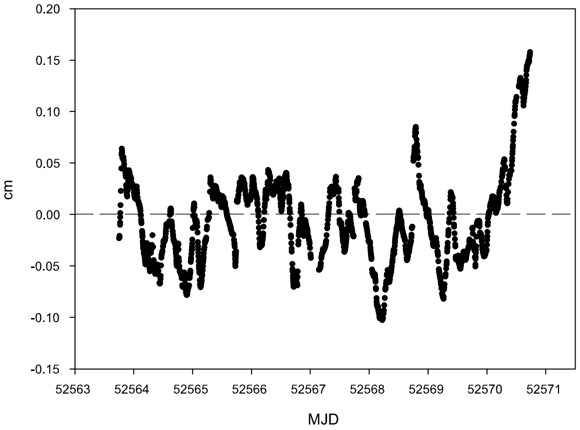

Figure 4. Variations of the east troposphere gradients for the Onsala VLBI site from the CONT02 campaign.

Time series of the wet troposphere delays and gradients have been calculated also. Figures 3,4 show variations of the troposphere gradients for the Onsala VLBI site during the first week of the CONT02 campaign.

5. Plans

- Implementation of the IAU Resolutions 2000;
- Complete SINEX output from the classical least-squares method including the CRF;
- Global solution by least squares method;
- Comparison of global solutions by LSM and LSCM;
- Development for Space VLBI data analysis (RadioAstron, VSOP-2).

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