DIRECT ESTIMATION OF TIDALLY INDUCED EARTH ROTATION VARIATIONS OBSERVED BY VLBI

S. ENGLICH, R. HEINKELMANN, J. BÖHM, H. SCHUH
Vienna University of Technology, Institute of Geodesy and Geophysics, Advanced Geodesy
Gußhausstraße 27-29, 1040 Vienna, Austria
sigrid.englich@tuwien.ac.at

ABSTRACT. The subject of our study is the investigation of periodical variations induced by solid Earth tides and ocean tides in Earth rotation parameters (ERP: polar motion, UT1)observed by VLBI. There are two strategies to determine the amplitudes and phases of Earth rotation variations from observations of space geodetic techniques. The common way is to derive time series of Earth rotation parameters first and to estimate amplitudes and phases in a second step. Results obtained by this means were shown in previous studies for zonal tidal variations (Englich et al., 2008a) and variations caused by ocean tides (Englich et al., 2008b). The alternative method is to estimate the tidal parameters directly within the VLBI data analysis procedure together with other parameters such as station coordinates, tropospheric delays, clocks etc. The purpose of this work was the application of this direct method to a combined VLBI data analysis using the software packages OCCAM (Version 6.1, Gauss-Markov-Model) and DOGSCS (Gerstl et al., 2001). The theoretical basis and the preparatory steps for the implementation of this approach are presented here.

1. DERIVATION OF TIDAL ERP VARIATIONS

Earth rotation parameters or Earth orientation parameters (ERP+precession-nutation), respectively, are usually estimated as linking elements between Earth-fixed and space-fixed reference frames, within the normal adjustment procedure. Periodical variations of the ERP are thereby introduced to get best possible a priori ERP, the values are taken from conventional models. The actually estimated quantities are small corrections to the a priori ERP values. ERP time series obtained in this way can then be used to determine the inherent periodical variations in a second adjustment independent from the general data analysis. The disadvantage of this strategy is that it is necessary to reduce signals with frequencies that are not of interest in the special case. For example, if the signals of interest are daily and sub-daily variations caused by ocean tides, a smoothed ERP series (i.e. low-frequency signal) has to be reduced from the original one. Thus additional a priori information is introduced. This step might insert artificial signal and hence influences the estimation of the tidal parameters.

In the direct approach the ERP are represented as a sum of the parameter in the absence of tidal effects and the variations due to solid Earth tides or ocean tides (e.g. Sovers & Jacobs, 1996). The partial derivatives of the unknown parameters of the variations are formulated (considering their periods as known) and are integrated into the functional model of the adjustment. New parameters are set up for ocean tidal variations with diurnal and semi-diurnal periods in all ERP and for zonal tidal variations with periods from around 5-365 days in UT1 only (the term zonal tidal variations comprises effects of solid Earth tides and long period ocean tides here). We use an extended parameterization for polar motion

$$x_p = x_{p_0} + \delta x_{p_{ot}}$$

$$y_p = y_{p_0} + \delta y_{p_{ot}}$$

and accordingly for Universal Time

$$UT1 = UT1_0 + \delta UT1_{zt} + \delta UT1_{ot}.$$

Quantities with the subscript 0 label the slowly varying parameter in the absence of ocean/zonal tidal variations, whereas δ and the subscripts ot or zt mark the corresponding variations. The representation (we write ERP substitutional for all parameters) for the ocean tidal variations reads

$$\delta ERP_{ot} = \sum_{i=1}^{n} [A_{i_{ot}} cos\xi_i + B_{i_{ot}} sin\xi_i] \quad with \quad \xi_i(t) = \sum_{j=1}^{6} N_{ij} F_j(t)$$

and similar for the zonal tidal variations

$$\delta UT1_{zt} = \sum_{i=1}^{m} [A_{i_{zt}} cos\xi_i + B_{i_{zt}} sin\xi_i] \quad with \quad \xi_i(t) = \sum_{j=1}^{5} N_{ij} F_j(t)$$

Where n and m specify the number of considered tidal terms, A_i and B_i denote the amplitudes corresponding to tidal wave i and ξ_i are the so-called fundamental arguments.
The software OCCAM still uses the transformation based on ecliptic and equator for the transfer from the celestial to the terrestrial reference frame. This means there is a rotation matrix for x_p and y_p and one for Greenwich sidereal time and therewith implicitly for UT1. If we name the corresponding matrix for each ERP R_{ERP} then the partial derivatives with respect to the tidal amplitudes can be simply written as follows

$$\frac{\partial R_{ERP}}{\partial A_i} = \frac{\partial R_{ERP}}{\partial ERP} \cdot \frac{\partial ERP}{\partial A_i} \quad with \quad \frac{\partial ERP}{\partial A_i} = sin\xi_i$$

and correspondingly w.r.t. B_i

$$\frac{\partial ERP}{\partial B_i} = cos\xi_i$$

2. DISCUSSION AND FUTURE TASKS

The intention of this work was to estimate coefficients of tidal ERP variations directly from VLBI group delay observations. The main advantage of this approach is that no additional information has to be introduced, which could distort the results. In this paper the basic formulation of the problem and the partial derivatives were presented. Within this study the above described approach was implemented and tested with the quoted software packages. We conducted a global solution which yielded preliminary results for 16 zonal tidal terms (UT1) and 13 ocean tidal terms (UT1, x_p, y_p). The results are not given here, because the realization of the method requires further examination before resulting values can be compared to conventional models.
The first tests were accomplished using a rather simple approach. It is intended to consider other periodic effects (such as atmospheric tides) in follow-up studies. Another future issue is the correlation between the newly introduced unknowns and other parameters of the adjustment which has to be investigated in more detail and handled appropriately.

3. REFERENCES

Englich S., Weber R., Schuh H., 2008, "Empirical validation of the conventional model for length of day variations due to zonal tides". Proceedings of the Journes 2007 "Systèmes de Référence Spatio-Temporels", N. Capitaine (ed.), Observatoire de Paris, pp. 184-187.

Englich S.,Heinkelmann R.,Schuh H., 2008, "Re-Assessment of Ocean Tidal Terms in High-FrequencyEarth Rotation Variations Observed by VLBI", in International VLBI Service for Geodesy and Astrometry 2008 General Meeting Proceedings, edited by Dirk Behrend and Karen Baver, Russian Science Series.

Gerstl M., Kelm R., Müller H., Ehrnsperger W., 2001, "DOGSCS Kombination und Lösung großer Gleichungssysteme", Deutsches Geodätisches Forschungsinstitut, DGFI Interner Bericht Nr. MG/01/1995 /DGFI.

Sovers O.J., Jacobs C.S., 1996, "Observation Model and Parameter Partials for the JPL VLBI Parameter Estimation Software "Modest"-1996", JPL Publication 83-39, Rev. 6, California Institute of Technology, Pasadena, California.