DIURNAL POLAR MOTION FROM VLBI OBSERVATIONS

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ABSTRACT. A new 15-years long time series of the Earth Rotation Parameters (polar motion and $UT1-UTC$) has been derived from the VLBI observations by the least square collocation method. Henceforward we focused our attention on the polar motion time series. It has a non-uniform time distribution and covers the time span from 1989 till 2004. The method of complex demodulation has been applied in order to extract from the series a signal in the diurnal frequency band. Amplitudes of polar motion variations at main tidal frequencies have been estimated and then compared with the model of atmospheric tidal variations.

1. INTRODUCTION

The Very Long Baseline Interferometry (VLBI) observations are used routinely to estimate the pole coordinates x and y as averages per 24-hour long observing sessions. Meanwhile, there is an interest to polar motion with sub-daily resolution. A typical VLBI session provides a few hundreds of observables per day. Thus, it is possible, in principle, to estimate polar motion with sub-diurnal resolution. The problem is that the VLBI observations are carried out normally only few times per week at most. In order to estimate polar motion time series with sub-diurnal resolution, special continuous VLBI campaigns have been organized, but they were, in turn, restricted in duration to the time intervals of two weeks.

The aim of this work is to obtain a few years long time series of diurnal polar motion by use of all available VLBI observations. This goal is achieved by applying the complex demodulation technique which allows to convert the high-frequency components of a signal into the low-frequency band.

2. VLBI DATA PREPROCESSING

In our analysis we used observations from 24-hour geodetic VLBI sessions from January 1989 till April 2004. Whole amount of the processed experiments was 987. The time span covered by these data was longer than 15 years.

In order to obtain a time series of Earth Rotation Parameters (ERP) with sub-diurnal resolution we applied the least-square collocation method (LSQM) as it is realized in OCCAM 6.0 software. In frame of this method, a model with 3 types of parameters is used (see Titov & Schuh, 2000):

$$Au + Bv + Cw + \xi = l, \tag{1}$$

where l is the vector of differences between the observed and calculated values (O-C); ξ is the vector of measurement errors; A, B, C are the matrices of partial derivatives; u, v, w are the vectors of parameters under estimation. The first group of parameters (vector u) includes only corrections to radiosourses positions. They were considered as global parameters, i.e. as having the same values for all sessions. The second group of parameters (vector v) was considered as 'daily', i.e. it was supposed that these parameters were constant during each 24-hours session. Among the parameters of this group were corrections to stations coordinates, offsets of the Celestial Ephemeris Pole as well as the statistical expectations of stochastic parameters. We treated the Earth Rotation Parameters (ERP – x, y coordinates of the pole, $UT1 - UTC$), clock rates and offsets, zenith delays and tropospheric gradients as stochastic processes (vector w).

The LSQ method allows to estimate vectors u, v and w in two stages. At first step an adjustment of global parameters u is made. At the second step, the vectors of 'daily' (v) and stochastic parameters (w) are estimated.

In our study an improvement of the existing Celestial Reference Frame (CRF) was not of interest, therefore we just fixed the the CRF to a priory catalogue ICRF-Ext.1. Thus we assumed that we know radiosourses coordinates quite exactly, i.e. $u = 0$. In this case model (1) with three groups of parameters could be reduced to the model with two groups of them (v, w). Estimations of these parameters for each VLBI experiment are given by

$$\hat{v} = (B^T {Q_0}^{-1} B)^{-1} B {Q_0}^{-1} l, \tag{2}$$

$$\hat{w} = Q_w C^T (C Q_w C^T + Q_\xi)^{-1} (l - B\hat{v}), \tag{3}$$

where $\hat{v}, \hat{w}$ are estimations of v, w vectors; Q_ξ, Q_w – the covariance matrixes of observational dispersions and stochastic parameters, respectively. We denoted as Q_0 the following matrix

$$Q_0 = C Q_w C^T + Q_\xi.$$

For more details concerning this procedure see Titov (2000), Titov & Schuh (2000).

As a result of applying the LSQM we derive unevenly sampled time series of the ERP. Note that in this series the model of the diurnal and sub-diurnal variations in polar motion and $UT1$ due to oceanic tides has already been taken into account. The model contains 71 diurnal and sub-diurnal terms and was calculated by R. Eanes based on the paper by Ray et al. (1994). The time resolution of the output ERP series is three to ten minutes during one session and two to seven days-long gaps between the sessions. As a result, it is needed to apply special methods of analysis.

3. EOP ANALYSIS

Hereafter we will consider series of polar motion only. In order to extract signals in the diurnal frequency band we used the method of complex demodulation. This method has been described in details for instance in Brzezinski et al. (2002). Here we only outline the main ideas of the method. After applying the demodulation transformation, frequencies ω are transformed into $\omega' = \omega - \sigma_0$, where σ_0 is the so-called demodulation frequency which could be chosen arbitrarily. In the time domain the initial time series of polar motion $f = x - iy$ will be changed as $f' = -fe^{-i\sigma_0 t}$. But in the frequency domain, due to the Fourier transform property, such transformation just shifts spectrum of the initial series by the value σ_0 such a way that $\omega = \sigma_0$ becomes 0.

In this work we used $\sigma_0 = \Omega$ in order to extract prograde diurnal motion, where Ω is a diurnal sidereal frequency equal to 1 cycle per sidereal day.

The advantage of the transformation is that variations with frequencies from the vicinity of σ_0 become long-periodical, i.e. slowly varying with time. All other variations are removed by a low-pass filter which in addition significantly reduce an amount of values in the time series under estimation.

Here we applied different methods of smoothing in order to check how the estimated parameters depend on the chosen method. The following methods have been applied: averaging by session (as the complex demodulation have already been applied such procedure does not change spectral constitution of the analyzed series in the prograde diurnal frequency band), the Gaussian filter (with the following parameters: full width at the half of maximum equal to 20 days and output time step of seven days) and the moving average.

4. DISCUSSION AND CONCLUSIONS

Combination of complex demodulation and smoothing allows to obtain an evenly sampled time series which contains a signal of sub-daily frequency band. Applying of a such technique gives us new possibilities in sub-daily variation study because it permit to use highly developed methods of analysis of equally spaced time series.

A least square fit of most powerful tidal components as well as a constant term has been made. In diurnal frequency band these components are $K1, P1$ and $S1$ with the corresponding frequencies after demodulation $\omega'_1 = 0$ (constant), $\omega'_2 = 1/182.61$ cpsd, $\omega'_3 = 1/365.20$ cpsd. To obtain residual variations at these frequencies we applied the following model:

$$x = \sum_{i=1}^{3} A_i sin(2\pi\omega'_i t) + B_i cos(2\pi\omega'_i t),$$

$$y = \sum_{i=1}^{3} A'_i sin(2\pi\omega'_i t) + B'_i cos(2\pi\omega'_i t).$$

Estimated amplitudes A_i, B_i and A'_i, B'_i obtained after applying of different smoothing methods are summarized in Table 1 and Table 2, correspondingly.

	K1	P1		S1	
	B_1	A_2	B_2	A_3	B_3
Gaussian filter	−3.2	−0.1	0.2	0.3	−0.7
averaging by session	−3.4	0.1	0.6	0.6	−1.2
moving average	−4.4	0.9	0.6	0.8	−1.6
demodulated series	−4.4	0.6	0.9	1.1	−1.4
Atmosphere (Petrov, 1998)				0.5	−0.8

Table 1: Amplitudes of main prograde diurnal harmonics in x-component of polar motion (μas).

These tables also contain amplitudes of the tidal components derived from the demodulated series without applying of any smoothing. Amplitude of the $S1$ term estimated from the atmospheric data (Petrov, 1998) is presented in the last row of each table. One can see that the S1 amplitude derived from VLBI observations is comparable to that from the atmospheric contribution. In order to compute this term we used the longest AAM series (NCEP/NCAR reanalysis)

	K1	P1		S1	
	B'_1	A'_2	B'_2	A'_3	B'_3
Gaussian filter	2.6	−0.3	−1.3	−1.3	1.0
averaging by session	3.0	−0.1	−1.3	−1.4	0.7
moving average	3.4	−0.9	−2.1	−2.4	0.9
demodulated series	3.4	−0.1	−2.2	−2.6	0.5
Atmosphere (Petrov, 1998)				−1.8	0.7

Table 2: Amplitudes of main prograde diurnal harmonics in y-component of polar motion (μas).

available (Salstein & Rosen, 1997), though we have to admit that different AAM series give different estimations of S1 amplitudes. Moreover, the atmospheric contribution has to be combined with the non-tidal oceanic influence, see Brzezinski et al. (2004) for detailed discussion.

A most important conclusion of this work is that it is possible to extract the high frequency components of ERP extending over several years, from the standard VLBI observations, without referring to the continuous campaigns. Our estimation of the prograde diurnal components of polar motion and comparison with the atmospheric excitation indicates that the method proposed here yields meaningful results.

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