NATURAL AND SYSTEMATIC POLAR MOTION JUMPS

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ABSTRACT. Polar motion consists mainly of two harmonic oscillations with variable phases and amplitudes and small irregular variations. The small irregular variations may be due to various geophysical excitations and observation inaccuracy (mostly in the first half of the last century). A part of irregular polar motion variations consists of fast jumps of the mean values of polar motion coordinates. The direct determination of the polar motion jumps is difficult, because the jump values are very small relative to the seasonal and Chandler amplitudes. A useful high sensitive method of data jumps determination is proposed. The method consists of data integration and piecewise linear or parabolic trends determination. This method is applied to determine the natural and systematic polar motion jumps existing in pole coordinates from the solutions OA10 for the period 1899.7–1962.0 and C04 for the period 1962.0-2013.5. Only a few of the determined polar motion jumps can be interpreted as systematic biases due to observational errors. The major part of the detected polar motion jumps occurs almost regularly near the epochs of minimum amplitude (due to the beat of seasonal and Chandler wobbles), so the natural origin of these jumps is supposed.

1. INTRODUCTION

The modern knowledge uses time series of many years' permanent observations. The data contain some small residual systematic deviations due to instrument and station changes. Determination of the systematic deviations from the mean values was applied in (Chapanov et al., 2007, 2008; Gambis et al., 2011) by means of linear trends in integrated time series. This approach is used here in a method of data and velocity jumps detection by means of parabolic and linear trends in integrated time series.

2. A HIGHLY SENSITIVE METHOD OF IMPULSE DETECTION

The method of data jumps determination consists of several steps. The first step is a removal of linear trend from the original data, followed by the integration of the resulting time series. The new integrated time series consists of oscillations with the amplitudes smaller than those in the original data and of the parts with visible piecewise significant linear or parabolic trends. The parts with linear trends of integrated data correspond to the constant mean behavior of the original data, the sudden changes of the linear trends occur at the epochs of the jumps in the original data. The parts of integrated data with significant parabolic trends point out to the linear variations of the original data. The second step of the method is the creation of the table containing all the epochs of data jumps. The next step consists in calculating the mean values or trends in the original data parts, corresponding to the table of jump epochs, and the last step is the calculation of jump values between neighboring data parts.

The time series are integrated numerically by the well known trapezoid rule. Let consider function f of argument x, discretized into $N+1$ equidistant points $f(x_i)$, $i = 1, 2, \ldots, N+1$. Let the first argument $x_1 = a$, and last argument $x_{N+1} = b$. Then the grid spacing is $h = (b-a)/N$ and the trapezoid approximation to the integral is

$$\int_a^b f(x)dx = \frac{h}{2}\sum_{k=1}^{N}(f(x_{k+1}) + f(x_k)) = \frac{b-a}{2N}(f(x_1) + 2f(x_2) + \ldots + 2f(x_N) + f(x_{N+1})) \quad (1)$$

To obtain the integral of a given time series $f(t_i)$, $i = 1, 2, \ldots, N+1$ it is necessary to integrate N times the function f with boundaries $a = t_1$ and $b = t_i$, $i = 2, \ldots, N+1$.

Any data jump of the original data will be expressed as a linear segment of the data after the jump epoch in the integrated time series. Any velocity jump of the original data will be expressed as a parabolic data behavior in the integrated time series.

3. POLAR MOTION JUMPS FOR THE PERIOD 1900-1962

Polar motion consists mainly of two harmonic oscillations with variable phases and amplitudes and small irregular variations. The small irregular variations may be due to various geophysical excitations and observation inaccuracy in the first half of the last century, too. A part of irregular polar motion variations consists of fast jumps of the mean values of polar motion coordinates. The direct determination of the polar motion jumps is difficult, because the jump values are very small relative to the seasonal and Chandler amplitudes.

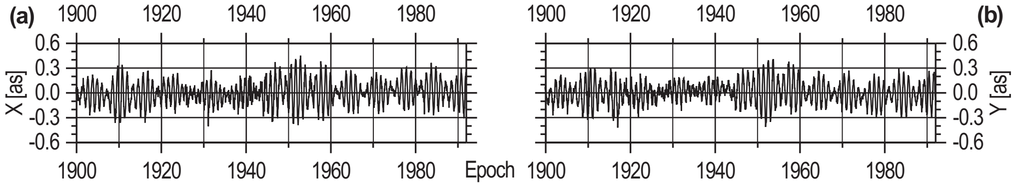

Figure 1: Detrended time series of polar motion coordinates from the solution OA10 of Vondrák et al. (2011).

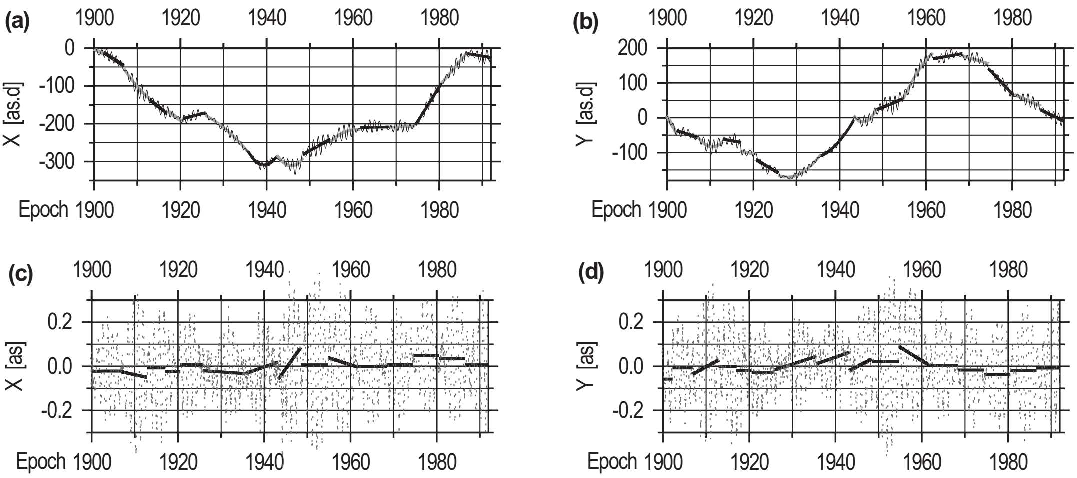

Figure 2: Integrated time series of detrended polar motion coordinates for the period 1900–1992 (thin lines) and their piecewise trends (bold lines) - (a), (b). Location of data and velocity jumps (bold segments) of polar motion coordinates (dashed lines) - (c), (d).

Fig. 1 presents the detrended time series of X and Y pole coordinates from the solution OA10 of Vondrák et al. (2011). The amplitude of polar motion beat is $0.2'' - 0.3''$. Significantly smaller jumps than the beat amplitude will be determined by the method described above. The integrated time series of X and Y pole coordinates from Fig. 1 are approximated by piecewise parabolic or linear trends (Fig. 2 a, b). The greatest part of the breaks between these trends occurs almost regularly in 6-year intervals during the time intervals with the least amplitude of seasonal and Chandler beat, so the natural origin of these jumps is supposed. The epochs of the trend breaks determine the epochs of data and velocity jumps, whose values for the period 1900-1962 are determined according the graphs in Fig. 2 b, c (Table 1). Only two jumps in 1902 and 1917.3 outside the polar motion minima are interpreted as systematic biases due to observational errors.

4. POLAR MOTION JUMPS FOR THE PERIOD 1962-2013

Polar motion jumps for the period 1962–2013 are determined from the detrended C04 solution after removing all oscillations from annual-Chandler frequency band, determined by 16 harmonics of partial Fourier approximation with periods between 0.97a–1.36a (Fig. 3 a, b). The integrals of the filtered data better represent the existing linear and parabolic trends (Fig. 4 a,b). The RMS errors of polar motion data show significant changes in 1968.0, 1972.0, 1980.0, 1984.0 and 1993 (Fig. 3 c). The first three epochs of the error decrease are connected with data jumps, so they are associated with the systematic errors. Most of the detected data and velocity jumps occur during the polar motion minima and they are probably due to some natural impulse phenomena. The coordinate X has data jump in 1991.2 outside the polar motion minima and this jump is possible to associate with data systematics. Another significant jump outside the polar motion minima occur in 2008.8, whose source of excitation is among the geodynamical events in that time, because it is not possible that one and the same systematic error can occur in all space technique observations.

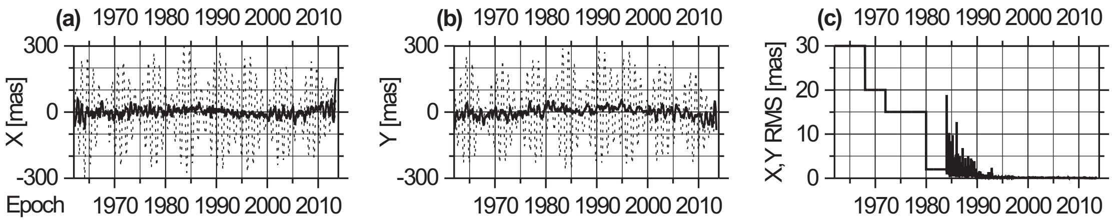

Figure 3: Polar motion detrended coordinates (dashed lines) and filtered data (bold lines) X (a) and Y (b) and their RMS errors (c) from the solution C04.

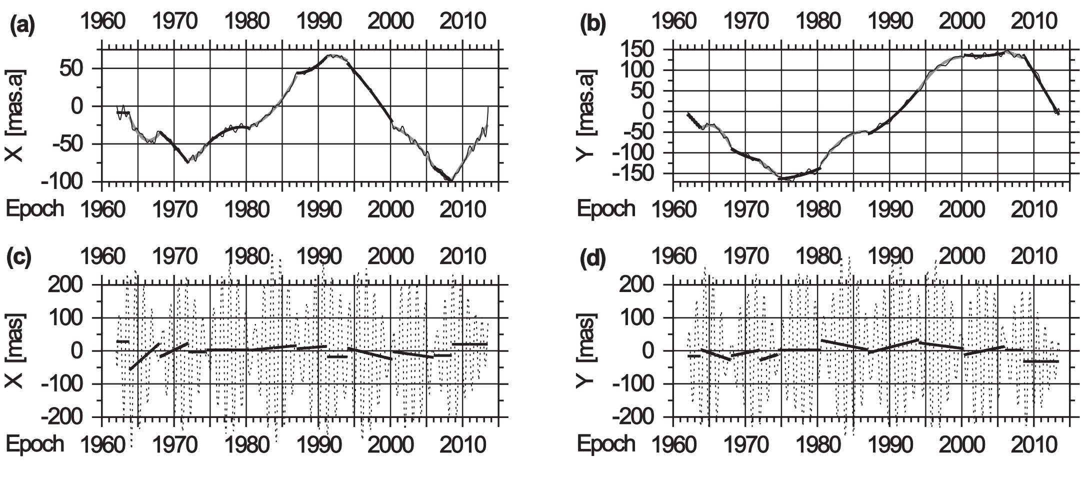

Figure 4: Integrated time series of detrended polar motion coordinates for the period 1962–2013 (thin lines) and their piecewise trends (bold lines) - (a), (b). Location of data and velocity jumps (bold segments) of polar motion coordinates (dashed lines) - (c), (d).

5. CONCLUSIONS

The method of data and velocity jumps determination based on the linear and parabolic trends in the integrated time series is highly sensitive to any impulse behavior of the observed variations due to various geophysical processes like earthquakes, tornadoes, hurricanes, geomagnetic jerks or to some systematic data deviations. The method is extremely sensitive to small data jumps hidden inside the level of random noise and high frequency oscillations of the data, because the integrated time series yield

Table 1: The epochs and values of data and velocity jumps of the coordinates X and Y of the polar motion for the period 1900–1962, determined from the solution OA10 and for the period 1962–2013, determined from the solution C04.

Epoch [years]	X Jumps [mas]	dX/dt Jumps [mas/a]	Y Jumps [mas]	dY/dt Jumps [mas/a]
1899.7	–22	0	–50	0
1902.0	–7	0	–7	0
1906.8	–7	-2.6	–10	+2.1
1912.8	+5	0	+5	0
1917.0	–16	0	–2	0
1920.5	+30	–6.8	–50	10.8
1925.8	–20	–0.8	–20	+6.5
1935.8	–50	+11.4	+15	+5.4
1942.8	–20	+8.8	+40	–12.9
1948.9	–16	0	–8	0
1955.2	+35	–6.5	0	–2.3
1962.0	+27 .3	0	–17.4	0
1963.8	–59.0	+20.0	+7.4	–9.0
1968.0	–18.0	+10.5	–14.6	+4.1
1972.0	–3.7	0	–28.8	+7.2
1974.5	+3.2	0	+2.6	0
1980.5	+1.8	+2.3	+31.7	–4.4
1987.0	+3.2	+3.8	–6.8	+5.7
1991.2	–8.5	–6.6	–	–
1994.1	+7.5	–5.2	+18.2	–2.0
2000.3	–2.1	–3.1	–4.9	+2.3
2006.0	–14.6	0	+1.9	0
2008.5	+8.4	0	–32.8	0

almost zero amplitude of high frequency terms, while the original data with mean linear or constant behavior yield magnitude in the integrated time series as large as the time intervals of these parts. The most of the detected data and velocity jumps occur almost regularly in 6-year intervals during the polar motion amplitude minima due to seasonal and Chandler beat, so the natural origin of these jumps can be supposed. Some systematics are connected with the error jumps in 1902, 1917.3, 1968, 1972, 1980, 1991.3. Anomalous polar motion jump occurs in 2008.5, when X increases by 8 mas and Y decreases by 33 mas, while during polar motion minima the jump magnitudes are less then 18 mas and less then 6 mas/a for the velocity. The 2008.5 anomaly probably prolongs the PM beat period up to 7–8 years.

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