A PRECESSION STUDY BASED ON THE ASTROMETRIC SERIES AND THE COMBINED ASTROMETRIC CATALOGUE EOC-2

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ABSTRACT. The new star catalogue EOC-2 has been used for the new solution of Earth Orientation Parameters (EOP) from optical astrometry over the interval 1899.7-1992.0. The same procedures as in the preceding solutions (c.f. Vondrák & Ron 2000) were followed, with two exceptions: 1. The IAU 2000 model of nutation and the improved P03 model of precession (Capitaine et al. 2003) were used which led to much smaller values of the celestial pole offsets (CPO), 2. the CPO in longitude and obliquity were represented by a constant, linear and quadratic terms instead of the 5-day individual values as before. The values obtained for the linear and quadratic terms of the CPO are compared and discussed in view of a possible validation of the P03 precession model.

1. MOTIVATION

After the 2003 implementation of the new IAU 2000A precession-nutation model, a considerable effort has been devoted to improving the precession quantities. The improved P03 precession model of Capitaine et al. (2003, 2004) that is consistent with the IAU 2000A model, but with revised linear and quadratic terms, has appeared recently. The analysis of the celestial pole offsets (CPO) obtained from VLBI can be used for improving the linear terms of precession but the too short time span of VLBI data (20 years) does not allow reliable quadratic fit in the residuals between the models and observations.

On the other hand, the work on the new astrometric catalogue EOC-2 (Vondrák & Ron, 2005) culminated in providing an improved solution of Earth orientation parameters from optical astrometry over the interval 1900-1992 (Ron & Vondrák, 2004). The length of the optical observations as compared with that of VLBI incited us to use the optical astrometry data for fitting the quadratic terms to the observed celestial pole offsets. Moreover, as the correction $\delta\dot{\psi}_A$ for the rate of the IAU 1976 precession model obtained from previous solutions of Earth orientation parameters from optical astrometry was in good agreement with that derived from VLBI (Vondrák & Ron, 2000), these data appear as being appropriate for determining precession.

2. SOLUTION FOR EARTH ORIENTATION PARAMETERS REFERRED TO EOC-2

The new catalogue EOC-2 is based on the recent catalogues ARIHIP, Tycho2, and Hipparcos combined with the observations of optical astrometry. The detailed description of its construction is presented in Vondrák & Ron (2005). The reference frame of EOC-2 has no motion with respect to the so-called “astronomically excellent” stars in ARIHIP, i.e. with respect to the optical representation of International Celestial Reference System (ICRS). The new catalogue is more accurate in the long-periodic sense (namely in proper motions) than the original catalogues. The procedure followed in this study is the same as that followed in the preceding solutions of Earth orientation parameters (see Vondrák & Ron 2000), but all observations were transformed using the IAU 2000A model of nutation (Mathews et al., 2002) and the P03 model of precession (Capitaine et al., 2003). Celestial pole offsets were represented by a constant, linear and quadratic term. The following parameters were derived:

- for each 5-day interval:
  - $x\,,y$ coordinates of the pole in the terrestrial reference frame,
  - Universal time differences UT1–TAI (after 1956),
- for each instrument and the whole interval:
  - constant, linear, annual and semi-annual deviation in latitude A, A_1, B, C, D, E,
  - constant, linear, annual and semi-annual deviation in universal time A', A'_1, B', C', D', E',
  - rheological parameter $\Lambda = 1 + k - l$ governing the tidal variations of the local vertical,
- for the whole interval:
  - celestial pole offsets $\Delta\varepsilon, \Delta\psi\sin\varepsilon$, each represented by a constant, linear and quadratic term.

All observations were recalculated to be related to the EOC-2 catalogue, and in this way also to the ICRS. The observation equations lead to the system of normal equations that are singular with defect of matrix equal to 18. Therefore it is necessary to add 18 constraints tying together the parameters $A, \ldots, E'$, fixing thus the terrestrial reference frame defined by the conventional coordinates of the individual instruments (see Tab. 1) and assuring that projection of seasonal deviations to axes x, y is minimized. The solution is described in details by Vondrák et al. (1998). We used the observations of the instruments listed in Tab. 1 where the coordinates defining the terrestrial system and the secular drifts of the stations caused by the movements of the lithospheric plates derived from the model NUVEL-1 NNR (DeMets et al., 1994), are shown.

The new solution of Earth orientation parameters (called OA04a), based on 4541385 of individual star/star pair observations made with 47 instruments (merged into 40 series), yielded 16462 estimated parameters. These comprises 6702 5-day values of x and y and 2628 5-day values of UT1–TAI, that are shown in Fig. 1, 393 station parameters, 6 parameters for the celestial pole offsets and 18 Lagrange multipliers for the constraints. The average standard error of one observation is $\sigma_0 = \pm 0.191''$ and the formal errors of the estimated parameters $\sigma_x = \pm 0.017''$, $\sigma_y = \pm 0.016''$, $\sigma_{UT} = \pm 0.72$ms.

The celestial pole offsets of the solution OA04a are referred to the IAU 2000A nutation and the P03 precession; they are expressed in mas by Eq. (1) for obliquity $\Delta\varepsilon$, and Eq. (2) for longitude $\Delta\psi\sin\ \varepsilon$:

$$\Delta\varepsilon = -6.1_{\pm 0.4} + 8.2_{\pm 1.1} \times T + 2.9_{\pm 3.5} \times T^2, \qquad (1)$$

$$\begin{array}{l} \text{correlation} \\ \text{coefficients} \end{array} \quad \begin{array}{ccc} 1.00 & & \\ -0.56 & 1.00 & \\ -0.61 & 0.25 & 1.00 \end{array}$$

$$\Delta\psi\sin\varepsilon = -7.1_{\pm 0.4} + 27.7_{\pm 1.1} \times T + 32.3_{\pm 3.5} \times T^2 \qquad (2)$$

$$\begin{array}{ccc} 1.00 & & \\ -0.58 & 1.00 & \\ -0.62 & 0.29 & 1.00. \end{array}$$

The formal errors of the estimated parameters are shown in the subscripts, T is the time elapsed since 1956 in Julian centuries. The celestial pole offsets with the confidence interval are drawn in Fig. 2.

Code	latitude φ_0	$\dot{\varphi}$	longitude λ_0	dλ	$\dot{\lambda}$	weights	
	° ’ ”	[”/cy]	° ’ ”	[s]	[s/cy]	v_φ	v_T
Visual zenith telescopes							
CA	39 08 09.149	+0.061	8 18 44.0			1.32	
CI	39 08 19.438	+0.002	−84 25 00.0			1.19	
GT	39 08 13.282	+0.012	−77 11 57.0			0.93	
KZ	39 08 02.093	+0.001	66 52 51.0			0.77	
MZZ,MZL	39 08 03.706	−0.045	141 07 51.0			0.98	
TS	39 08 10.937	+0.004	63 29 00.0			0.94	
	39 08 11.301	+0.004	63 29 00.0			MJD>18512	
UK	39 08 12.141	+0.025	−123 12 35.0			0.99	
BLZ	44 48 10.456	+0.041	20 30 50.0			0.94	
BK	50 19 09.620	−0.048	127 30 00.0			1.79	
IRZ	52 16 44.381	−0.033	104 20 42.7			0.89	
POL	49 36 13.085	+0.031	34 32 52.0			0.89	
PU,PUZ	59 46 15.641	+0.034	30 19 39.0			1.10	
TT	60 24 57.517	+0.040	22 27 00.0			2.17	
VJZ	52 05 56.206	+0.041	21 00 00.0			0.70	
Photoelectric transit instruments							
IRF	52 16 44.0		104 20 42.0	−0.0086	+0.0084		0.89
KHF	50 00 00.0		36 13 58.0	+0.0054	+0.0083		0.94
NK	46 58 18.0		31 58 28.0	+0.0100	+0.0078		1.04
PUF/G/H	59 46 18.0		30 19 38.0	+0.0048	+0.0096		1.34
WHF	30 32 28.9		114 20 41.4	+0.0132	+0.0060		0.81
Photographic zenith tubes							
MZP,MZQ	39 08 02.795	−0.045	141 07 52.0	−0.0053	−0.0005	0.76	0.76
OJP	49 54 55.107	+0.044	14 47 09.0	+0.0121	+0.0072	1.30	1.45
PIP	−35 20 40.635	+0.036	−57 17 09.0	+0.0360	−0.0005	2.14	1.74
RCP,RCQ	25 36 47.038	+0.008	−80 22 56.0	+0.0020	−0.0027	1.31	1.14
WA,W,WGQ	38 55 17.224	+0.012	−77 03 56.0	+0.0014	−0.0044	1.15	0.92
MS	−35 19 17.443	+0.182	149 00 19.0	+0.0322	+0.0049	1.09	0.93
Astrolabes, Photoelectric astrolabes, Circumzenithals							$v_{\delta h}$
BJB	40 06 03.980	−0.042	116 19 40.9	+0.0038	+0.0066		0.96
BRC	48 09 17.757	+0.044	17 07 11.5	+0.0241	+0.0072		0.50
GRD	43 44 55.359	+0.049	6 55 36.0	+0.0767	+0.0063		1.19
PA	48 50 09.254	+0.051	2 20 15.7	−0.0145	+0.0063		0.89
PRE	50 04 40.030	+0.044	14 42 00.3	+0.0375	+0.0072		0.92
PRD	50 06 20.386	+0.044	14 23 20.3	+0.0368	+0.0072		0.67
PYD	49 54 55.590	+0.044	14 47 20.2	−0.0043	+0.0072		0.60
SC	−33 23 57.101	+0.058	−70 32 42.7	+0.0050	+0.0045		0.64
SIA	44 24 12.368	+0.031	33 59 48.6	+0.0113	+0.0076		0.50
SXA	34 56 43.585	−0.037	109 33 04.9	−0.0080	+0.0065		0.90
SXB	34 20 35.792	−0.037	109 08 05.0	+0.0201	+0.0065		0.65
WHA	30 32 29.152	−0.041	114 20 42.2	−0.0116	+0.0060		0.65
YUB	25 01 45.347	−0.032	102 47 41.2	−0.0536	+0.0060		1.65
ZIA	31 11 25.148	−0.045	121 25 37.6	−0.0024	+0.0059		0.79
ZIB	31 11 26.187	−0.045	121 25 39.2	+0.0003	+0.0059		1.22

Table 1: The coordinates φ_0 and λ_0 of the instruments used in the solution OA04a, referred to the mean epoch $\mathrm{MJD}_0 = 32000$ for the latitude and 43000 for the time and equal altitude observations; $\dot{\varphi}$ and $\dot{\lambda}$ are the secular drifts of the stations and v are the weights of observations used in the solution.

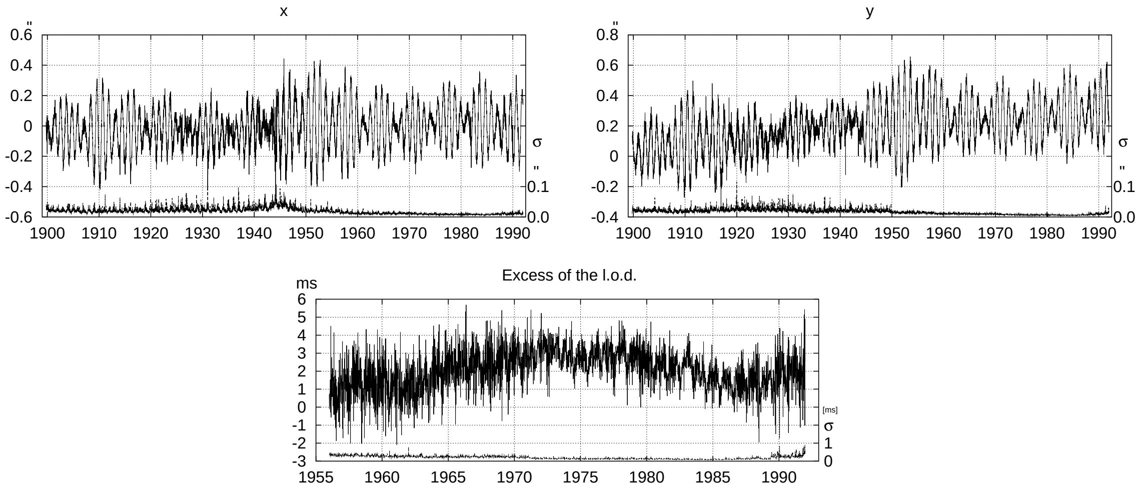

Figure 1: Solution OA04a: Polar motion x, y and excess of the l.o.d. over the nominal value 86400 s at 5-day intervals, and their standard errors. The short-periodic tidal variations in l.o.d. ($P < 35$ days) after Yoder et al. (1981) are removed.

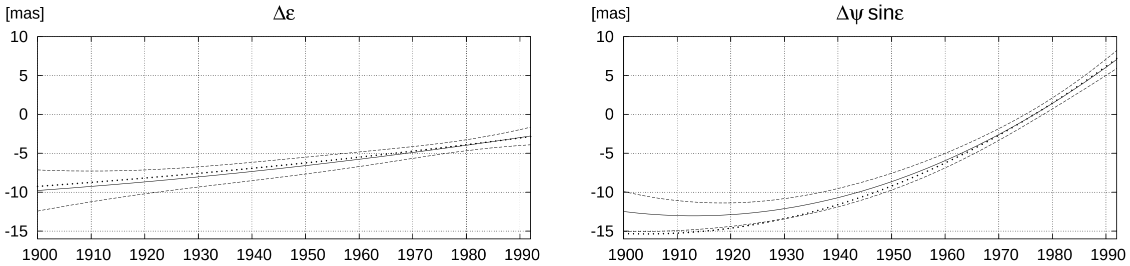

Figure 2: Solution OA04a: Celestial pole offsets in obliquity and longitude, referred to the IAU 2000A nutation and P03 precession models. The dashed curves define the 99% confidence interval. The dotted line shows the celestial pole offsets referred to the IAU 2000 precession.

We also estimated a solution referred to the IAU 2000 precession in order to check the implementation of the P03 precession into the solution OA04a. We used the same procedure and the same data with the exception of the P03 precession. The formal errors and the correlation coefficients are the same as in the solution OA04a. The values of the celestial pole offset referred to the IAU 2000 precession, drawn by the dotted line in Fig. 2, are the following

$$\begin{aligned} \Delta\varepsilon &= -5.8_{\pm 0.4} + 7.4_{\pm 1.1} \times T + 2.2_{\pm 3.5} \times T^2, \\ \Delta\psi \sin\varepsilon &= -7.5_{\pm 0.4} + 30.3_{\pm 1.1} \times T + 29.2_{\pm 3.5}. \times T^2 \end{aligned} \tag{3}$$

3. DISCUSSION

The improved P03 precession model of Capitaine et al. (2003) contains improved expressions for the motion of the ecliptic and for the contributions to precession and obliquity rates of the equator with respect to a fixed frame. The quadratic terms have been revised, due to the consideration of the secular change of the Earth's dynamical ellipticity. But the short time span of VLBI observations does not allow a reliable quadratic fit in the residuals between the models and the observations.

The celestial pole offsets from optical astrometry referred to the P03 precession and derived from the 92-year interval was at hand to determine the correction for the quadratic term of precession. The celestial pole offsets contain the inaccuracies in the P03 precession, but we have to pay attention to the inaccuracy of the link between the Hipparcos reference frame and ICRS of the order of ±0.25mas/y (Kovalevsky et al., 1997). The Hipparcos catalogue is a representation of the ICRS in the visible light range. The value of the linear term of the celestial pole offsets obtained from the optical astrometry is comparable to this inaccuracy (+0.08mas/y in case of obliquity, +0.27mas/y in case of longitude, see Eqs. (1, 2)). For that reason, it is not possible to distinguish between the real error of precession rate and a possible slow rotation of EOC-2 with respect to ICRS. Thus we cannot use the linear term for deriving the correction of the precession rate. The quadratic term in longitude from optical astrometry is improbably too big and cannot be used either for confirmation or refutation of the P03 model. The linear term could be explained by the rotation of the Hipparcos reference frame with respect to distant extragalactic objects, but the big quadratic term in longitude remains unexplained and deserves further study.

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