Perugia, Italy July 2-13, 2007

IUGG XXIV 2007 PERUGIA ITALY

EARTH: OUR CHANGING PLANET

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Session GS003 Earth Rotation and Geodynamics

CHANDLER AMPLITUDE AND PHASE DECADE OSCILLATIONS OF THE EARTH POLE AND CORRESPONDING VARIATIONS OF GEOPOTENTIAL COEFFICIENTS C21 AND S21

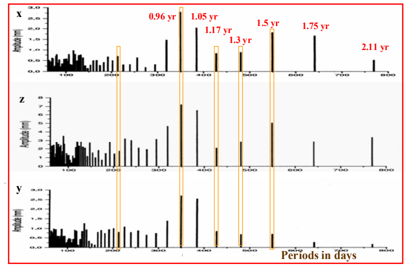
A dynamic explanation and an analytical description of observable decade variations of amplitude, period and phase of Chandler perturbed motion of the Earth pole (Ach, Tch and Fch) is given. It has been shown, that observable Chandler motion of the pole has the forced character (Barkin, 2000). The basic role in excitation of pole motion and in maintenance of the basic oscillation with the periods about 430 days play variations of products of inertia of the Earth with the periods close to unperturbed Chandler pole motion. According to developed geodynamic model (Barkin, 2002) the forced oscillations of system of outer core and elastic mantle (and, accordingly, the displacements of the centre of mass of the Earth) under gravitational attraction of the Moon and the Sun are characterized by known frequencies of orbital motions of system the Earth - the Moon - the Sun (or by some combinations of these frequencies). The same frequencies characterize variations of the tension of the mantle layers, cyclic redistributions of masses of atmosphere, oceanic masses, subsoil waters and other fluids. These processes determine corresponding variations of the moments of inertia and geopotential coefficients which obtain dynamic reflection in axial rotation of the Earth and in its pole motion. The specified positions have obtained a set of confirmations according to astronomical, geodetic and geophysical observations. In the given work it is shown, that perturbations of the Earth system on the part of the Moon and the Sun with frequencies from a vicinity of Chandler unperturbed frequency and its double value lead to decade perturbations of parameters Ach, Tch and Fch. The analytical description is given to the specified perturbations on the basis of the special form of the equations of rotary motion in Andoyer variables for weakly deformable bodies (Barkin, 2000). Let's result the periods of orbital perturbations of the Moon to which there correspond translational oscillations of the core and elastic mantle (the last determine decade changes of amplitude and phase of perturbed pole motion): 411.8 d [40.7 yr], 409.2 [33.06 yr], 205.9 d [20.3 yr], 388.3 d [12.78 yr], 386.0 d [11.92 yr], 199.8 d [9.67 yr], 365.3 d [7.27 yr], 346.6 d [5.22 yr], 329.8 d [4.08 yr], 182.6 d [3.63 yr], 177.8 d [3.04 yr], 173.3 d [2.61 yr]. In square brackets theoretical values of the decade and interannual periods of perturbations in amplitude and a phase are given. Close values of the periods of perturbations in envelopes of pole coordinates are revealed on the basis of the data of observations (Kolaczek, Kosek, 1998; Nastula et al., 1993; Lapaeva, 2000; Vondrak, 1999 etc.). The predicted variations in position of a geocenter with the mentioned above periods (in days) have obtained confirmation as a result of the spectral analysis of coordinates of a geocenter, and also in variations of coordinates of the Earth pole. In particular the perturbations with periods (in days) were revealed: 217.11.1, 196.1 1.1, 367.60.8, 344.22.0, 317.02.2, 183.60.6, 175.22.0, 173.50.4 and others (Kaftan et al., 2003; Gayazov, 2003). On the basis of analytical formulas for amplitudes of variables: Ach, Tch and Fch on the data on observable decade variations of amplitude and phase Chandler amplitudes and phases of the appropriate variations of products of inertia of the Earth and factors of geopotential C21, S21 have been determined. Amplitudes have values about 0.2-0.5x10 (-10), that proves to be true the data of satellite laser observations (Gayazov, 2003).

References

Barkin, Yu.V. (2000a) Perturbated rotational motion of weakly deformable celestial bodies. Astronomical and Astrophysical Transactions, Vol.19, Issue 1, pp. 19-65.

Barkin, Yu.V. (2000b) A mechanism of variations of the Earth rotation at different timescales. In: Polar Motion: Historical and Scientific Problems (Eds. Steven Dick, Dennis McCarthy, and Brian Luzum)/ Proceedings of IAU Colloquium 178 (Cagliari, Sardinia, Italy, 27-30 September 1999). Astronomical Society of the Pacific conference series, V. 208. Sheridan Books, Chelsia, Michigan. pp. 373-379.

Unity of spectrums of frequencies of oscillations of coordinates of geocenter x, y and z (Gajazov, 2003; ILRS data)



Main long-period effect in the pole motion with period

$$T_{\nu yrs} = \frac{2\pi}{\Omega_{1,0,0,-1,0} - \Omega_{CH}^{(0)}} = 38.6 \ years$$

$$\delta\theta = 0.07800'' \sin(l_M - D + l + \lambda) + 0.00116'' \sin(l_M - D - l - \lambda)$$

$$\delta T_{CH}^{PM} = T_{CH}\left[0.01340 \sin(l_M - D + l + \lambda) - 0.01340 \sin(l_M - D - l - \lambda)\right]$$

$\theta = \theta_0$, $l = -\cos\theta \Omega_{CH} t + l_0$ is a zero approximation: θ_0, l_0 are initial values of the corresponding variables: $\theta_0 = 0.175''$, $T_{1,0,0,-1,0} = 2\pi / \Omega_{1,0,0,-1,0} = 411.78$ days, $T_{CH} = 424.16$ days, $\nu = (1,0,0,1,0)$.

Variations of the products of inertia

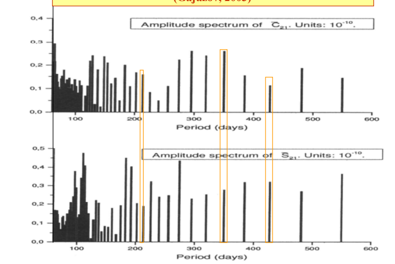
$$\delta E / C_0 = 0.3608 \cdot 10^{-10} \cos(l_M - D + \lambda)$$
$$\delta D / C_0 = 0.3608 \cdot 10^{-10} \sin(l_M - D + \lambda)$$

Some theoretical and observed parameters of the Earth pole motion

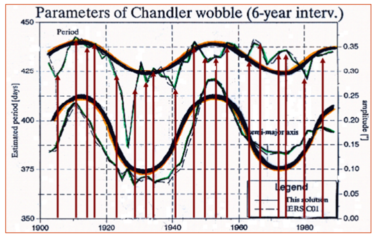
Amplitude	Theory	Observations
θ_0	0"175	0"16
θ_{max}	0"250	0"22-0"28
θ_{min}	0"100	0"06--0"14
$\Delta\theta$	0"150	0"14-0"16

Period (days)	Theory	Observations
$T_{CH}^{(0)}$	430.9	432
$T_{CH,max}$	437	438
$T_{CH,min}$	426	426
ΔT_{CH}	11	12

Unity of spectrumes of variations of geopotential coefficients (Gajazov, 2003)



Variations of period and amplitude of Chandler motion in 1900-2000



LIOUVILLE EQUATIONS (Liouville, 1858; Tisserand, 1891)

$$\frac{d}{dt}(Ap - Fq - Er + P) + D(r^2 - q^2) + (C - B)qr + (Fr - Eq)p + qR - rQ = L_\xi,$$
$$\frac{d}{dt}(-Fp + Bq - Dr + Q) + E(p^2 - r^2) + (A - C)rp + (Dp - Fr)q + rP - pR = L_\eta,$$
$$\frac{d}{dt}(-Ep - Dq + Cr + R) + F(q^2 - p^2) + (B - A)pq + (Eq - Dp)r + pQ - qP = L_\zeta.$$

Components of tensor of inertia and components of relative angular moment of body particles

$$A(t),\ B(t),\ C(t);\ F(t),\ E(t),\ D(t);\ P(t),\ Q(t),\ R(t).$$

Barkin Yu.V., Ferrandiz J.M.: Unity of Rhythms of Earth Rotation, Gravity and Geodesy Variations 313

Table 1. General base of periods.

a) Short periods (in days)			b) Interannual and decade periods (in years)			
476 (471.9)	172 (173.3)	504	102	7.09	22.39	70.00
415 (411.9)	161 (169)	40.4 (39.0)	1.41	8.00	25.92	73.00
402 (409.2)	152	38.1 (38.5)	1.62	8.58	27.63	76.23
380 (386.0)	146	30.5 (29.8)	183	9.02	30.25	80.25
365 (365.3)	140	27.4 (27.4)	2.11	9.49	32.99	88.08
346 (346.6)	131 (131.7)	19.4	2.49	10.10	37.63	99.60
326 (329.8)	122 (121.8)	15.9 (15.9)	2.80	10.99	40.69	112.0
285	113 (117.5)	13.8 (13.8)	3.25	12.05	46.31	116.4
237	100 (96.8)	9.02 (9.06)	3.54	13.24	49.72	147.0
221 (212.3)	90.7 (91.3)	7.24 (7.24)	4.10	14.66	52.60	160.0
206 (205.9)	80.4	6.76 (6.86)	4.70	16.23	55.53	181.7
200 (199.8)	765		5.19	17.06	58.54	211.0
192 (193.6)	698		5.97	18.68	62.77	344.0
183 (182.6)	60.1		658	2010	6643	5390

Table. Periods of perturbations in lunar orbital motion, in geocenter position and in Chandler amplitude of pole motion. Unperturbed period 435.55 days.

ν_1	ν_2	ν_3	ν_4	ν_5	ν_6	T_ν (in days)	Theory (in yr.)	Periods of variations of Chandler amplitude (in years)	Periods of variations in geocenter position (in days)
1	0	0	-1	0	1	411.8 (1.1275)	40.70	41.0; 40.5 (K), 40 (N), 40 (L)	
0	1	0	0	2	1	409.2 (1.1203)	33.06	31.0 (V), 30 (N), 30.8; 30.4 (K)	
2	0	0	-2	0	2	205.9 (0.5637)	20.30	19.5; 18.7 (K), 20 (N), 20.2 (V), 22.2 (G-M)	217.1 ± 1.1
-1	0	0	1	1	-1	388.3 (1.0631)	12.78	13.5 (V)	
0	1	0	0	1	1	386.0 (1.0568)	11.92	12.0 (N), 11.8 (G-M), 11(N)	
-2	0	0	2	1	-2	199.8 (0.5470)	9.67	10.1 (K), 10.2 (KK), 10.4 (G-M)	196.1 ± 1.1
0	1	0	0	0	1	365.3 (1.00)	7.27	7.9 (KK),	367.6 ± 0.8
0	-1	0	0	1	-1	346.6 (0.9489)	5.22	5.85 (V), 6.0 (G-M), 6.0 (Sid)	344.2 ± 2.0
0	1	-2	2	0	-1	329.8 (0.9029)	4.08		317.0 ± 2.2
0	2	0	0	0	2	182.6 (0.4999)	3.63	3.6 (KK), 3.6 (Sid)	183.6 ± 0.6
0	0	2	-2	1	2	177.8 (0.4868)	3.04	3.3 (KK)	175.2 ± 2.0
0	0	2	-2	0	2	173.3 (0.4745)	2.61	2.8; 2.4 (Sid)	173.5 ± 0.4

Non-canonical Equations of Rotational Motion of a Deformable Body in Andoyer Variables

$$\frac{dG}{dt} = L_{G_3},$$
$$\frac{d\rho}{dt} = -\frac{1}{G} L_{G_2},$$
$$\frac{dh}{dt} = \frac{1}{G} \sec\rho L_{G_1},$$
$$\frac{d\theta}{dt} = G\sin\theta\left[\frac{1}{2}(a-b)\sin 2l - f\cos 2l\right] + G\cos\theta(d\sin l - e\cos l) + \beta\sin l - \alpha\cos l + \frac{1}{G}(L_{G_2}\cos g - L_{G_1}\sin g),$$
$$\frac{dl}{dt} = G\cos\theta(c - a\sin^2 l - b\cos^2 l + f\sin 2l) + G\sec\theta(e\sin l + d\cos l)\cos 2\theta - \gamma + \cot\theta(\alpha\sin l + \beta\cos l) + \frac{1}{G}\mathrm{cosec}\,\theta(L_{G_1}\cos g + L_{G_2}\sin g),$$
$$\frac{dg}{dt} = G(a\sin^2 l + b\cos^2 l - f\sin 2l) - G\cot\theta(e\sin l + d\cos l) - \sec\theta(\alpha\sin l + \beta\cos l) - \frac{1}{G}\cot\rho L_{G_1} - \frac{1}{G}\cot\theta(L_{G_1}\cos g + L_{G_2}\sin g).$$