ON THE NON-TIDAL SECULAR ACCELERATION OF THE EARTH'S ROTATION

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Резюме: *Исходя из наблюдаемого векового уменьшения второй зональной гармоники* [5], *вычислено добавочное положительное вековое ускорение земного вращения. Отмечено его соответствие наблюдаемому вековому уменьшению угловой скорости вращения Земли, т.к. последнее по абсолютной величине меньше, чем должно быть по океаническим приливам.*

Summary: *The secular positive acceleration of the Earth's rotation has been computed on the basis of the observed secular decrease of the second zonal harmonic* [5]. *It corresponds to the observed secular deceleration of the Earth's rotation which should be greater because of oceanic tides.*

The observed secular decrease of the angular velocity of the Earth's rotation may be estimated as [1, 2]

$$\mathrm{d}\omega/\mathrm{d}t = -(5{\cdot}4 \pm 0{\cdot}5) \times 10^{-22}\,\mathrm{rad\,s^{-2}}\,. \tag{1}$$

The Moon's and Sun's tidal torque is responsible for this geodynamic phenomenon. However, the ocean tides prescribe a significantly larger absolute value [3] in comparison with (1):

$$(\mathrm{d}\omega/\mathrm{d}t)_{\mathrm{tidal}} = -(7 - 8) \times 10^{-22}\,\mathrm{rad\,s^{-2}}\,. \tag{2}$$

We face the fact that a significant contradiction exists which should be explained. This means that a mechanism positively accelerating the rotation of the Earth additionally should be found [3], at least amounting to

$$\delta\mathrm{d}\omega/\mathrm{d}t \sim +1{\cdot}6 \times 10^{-22}\,\mathrm{rad\,s^{-2}}\,. \tag{3}$$

Recently, a secular decrease of the second zonal harmonic J_2 of the geopotential was found on the basis of the LAGEOS satellite orbit dynamics [4]. The refined value presented during the discussion to [5] at the XXVth COSPAR meeting in 1984 (Graz) is about

$$\mathrm{d}J_2/\mathrm{d}t = -(2{\cdot}6 \pm 0{\cdot}6) \times 10^{-9}\,\mathrm{cy^{-1}}\,. \tag{4}$$

This phenomenon should give rise to variations in vector ω. However, for computing it we need variations in the Earth's inertia tensor corresponding to (4). Because of the lack of data, we pose the conditions [7]

$$\mathrm{d}A/\mathrm{d}t + \mathrm{d}B/\mathrm{d}t + \mathrm{d}C/\mathrm{d}t = 0\,, \quad D = E = F = 0\,, \quad B = A\,; \tag{5}$$

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$C > B$, A are the principal moments of the Earth's inertia; D, E, F the products of inertia.

Then

(6) $$C^{-1}\,\mathrm{d}C/\mathrm{d}t = -5{\cdot}2 \times 10^{-9}\,\mathrm{cy}^{-1}\,,\quad \mathrm{d}C/\mathrm{d}t = -4{\cdot}2 \times 10^{29}\,\mathrm{kg}\,m^2\,\mathrm{cy}^{-1}\,,$$

(7) $$A^{-1}\,\mathrm{d}A/\mathrm{d}t = 2{\cdot}6 \times 10^{-9}\,\mathrm{cy}^{-1}\,,\quad \mathrm{d}A/\mathrm{d}t = 2{\cdot}1 \times 10^{29}\,\mathrm{kg}\,m^2\,\mathrm{cy}^{-1}\,;$$

$$C = 8{\cdot}036 \times 10^{37}\,\mathrm{kg\,m}^2\,,\quad A = 8{\cdot}010 \times 10^{37}\,\mathrm{kg\,m}^2\,.$$

In [8] variations $\delta\omega$ were computed for the period 1976 ~ 1982 corresponding to δJ_2 based on the condition $C\omega = \mathrm{const}$. In [6] the theory was given for variations in the vector ω caused by (4) under conditions (5). From this solution it follows that

(8) $$\frac{\mathrm{d}\omega_3}{\mathrm{d}t} = -\frac{1}{C_0}\frac{\mathrm{d}C}{\mathrm{d}t}\left(1 - \frac{1}{C_0}\frac{\mathrm{d}C}{\mathrm{d}t}\,t\right)\omega_3\,;$$

C_0 is the value of C for the initial epoch $t = 0$.

For a very short interval of time we can put

(9) $$\mathrm{d}\omega_3/\mathrm{d}t = \mathrm{d}\omega/\mathrm{d}t = -(\omega/C)\,\mathrm{d}C/\mathrm{d}t\,.$$

Numerically, with (6), we get

(10) $$(\mathrm{d}\omega/\mathrm{d}t)_{\text{non-tidal}} = +1{\cdot}2 \times 10^{-22}\,\mathrm{rad\,s}^{-2}\,.$$

This value is close to (3) and that is why it is possible to believe that conditions (9) might be considered as realistic. However, the magnitude of $(\mathrm{d}\omega/\mathrm{d}t)_{\text{non-tidal}}$ varies in time even if (1) and (2) are taken as constant; it increases slightly with time. This means, the tidal deceleration of the Earth's rotation should have been stronger in the past. The angular momentum $C\omega$ slightly decreases because of the lunar tidal torque and decreasing orbital angular momentum of the Moon. Recently,

(10) $$(C\omega)^{-1}\,\mathrm{d}(C\omega)/\mathrm{d}t = C^{-1}\,\mathrm{d}C/\mathrm{d}t + \omega^{-1}\,\mathrm{d}\omega/\mathrm{d}t = -2{\cdot}9 \times 10^{-8}\,\mathrm{cy}^{-1}\,,$$
$$\mathrm{d}(C\omega)/\mathrm{d}t = -5{\cdot}4 \times 10^{35}\,\mathrm{kg}\,m^2\,\mathrm{cy}^{-2}\,.$$

CONCLUSIONS

a) The observed decrease of the second zonal harmonic (4) corresponds well to the observed secular deceleration of the Earth's rotation (1).

b) The time interval of validity for (4) might be considered the same as for (1) and (2), i.e. the computation of J_2, using (4), for the period of validity of (1) appears to be realistic.

c) The explanation of (4) is to be sought in a geodynamic phenomenon existing during the whole time interval of validity of (1).

d) The recomputation of (2) on the basis of recent cotidal maps is urgently needed for controlling conclusions a)–c) which should be considered as preliminary. Also a re-examination of conditions (5) is necessary to be able to draw final conclusions.

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References

[1] Н. Н. Парийский: К изучению земных приливов. Физ. Земли, 9 (1978), 43.
[2] K. Lambeck: Tidal Dissipation in the Oceans: Astronomical, Geophysical and Oceanographic Consequences. Phil. Trans. Roy. Soc. London, 287 (1977), 545.
[3] Н. Н. Парийский, М. В. Кузнецов, Л. В. Кузнецова: О влиянии океанических приливов на вековое замедление вращения Земли. Физ. Земли, 2 (1972), 3.
[4] J. O. Dickey, J. G. Williams, XX Newhall, C. F. Yoder: Geophysical Applications of Lunar Laser Ranging. Pres. XVIIIth Gen. Ass. IUGG, Hamburg 1983.
[5] B. D. Tapley, B. E. Schutz, R. J. Eanes: Geodetic and Geophysical Parameter Determination from Satellite Laser Ranging. Pres. XXVth COSPAR Gen. Ass., Graz 1984.
[6] M. Burša, M. Šidlichovský: Influence of Time Variation in the Second Zonal Harmonic on Polar Motion. Bull. Astron. Inst. Czechosl., 36 (1985), 24.
[7] W. H. Munk, G. T. F. MacDonald: The Rotation of the Earth. Cambridge Univ. Press 1960.
[8] C. F. Yoder, J. G. Williams & J. O. Dickey, B. E. Schutz, R. J. Eanes & B. D. Tapley: Secular Variation of Earth's Gravitational Harmonic J_2 Coefficient from Lageos and Nontidal Acceleration of Earth Rotation. Nature, 303 (1983), 757.