UNITY OF RHYTHMS OF EARTH ROTATION, GRAVITY AND GEODESY VARIATIONS: THEIR NATURE AND INVERSION PHENOMENON

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Abstract. Unity of cyclycities and rhythms of natural processes on the Earth, Moon and Sun is discussed on the base of extensive materials and data of observations. Tidal mechanism and shell-mechanism of gravitational interaction in the Eaarth-Moon-Sun system are suggested for explanation of unity of natural processes. A phenomenon of inversion in variations of geoprocesses with respect to opposite hemispheres of the Earth is established as fundamental and universal for celestial bodies. This phenomenon must be observed in different time-scales. Mechanism of this phenomenon we connect with forced relative displacements of main shells of the Earth (core and mantle).

Introduction. Gravitational action of the Moon and the Sun generates tides on the Earth and big additional mechanical forces and moments of interaction of its neighboring shells (liquid core, mantle, another layers, plates) and produces cyclic perturbations of the tensional state of the shells, their deformations, small relative translational displacements and small relative rotational oscillations of the shells, redistribution of the plastic and fluid masses and others. These additional forces and moments of the cyclic celestial-mechanical nature produce deformations of the all layers of the Earth and dictate and control variations practically of all natural processes. In given report we analyze these forces and moments caused by Moon attraction. They are conditionally periodic functions of time with definite basis of frequencies, which are some combinations of the frequencies of perturbations in the Moon and Sun orbital motion. Important conclusion follows from our approach - natural planetary processes are controlled and dictated by pointed mechanisms and are subjected by cyclic variations with general for all processes base of frequencies. The fundamental basis of frequencies was established in result of theoretical study of the gravitational interaction of the Earth's core and mantle with the Moon and the Sun and in result of empirical analysis of observed variations of the many natural processes in last century (Barkin, 2002).

Predicted periods of variations of the natural processes were effectively conformed by results of the spectral analysis of various processes in nature and society (Gamburzev et al., 2002). In the paper we illustrate a prediction of gravity variations at Moscow fidicial station and by similar studies of the Earth rotation, vertical crust deformations (Kaftan, 2002). In particular periods, amplitudes (in a few microGal) and phases for about 20 harmonics of gravity variations were discovered in result of spectral analysis of the absolute gravimetric measurements. Interannual periods (in years): **1.03** (1.02)**, 1.58** (1.62), **2.49** (2.49), **6.00** (5.97), **10.7** (10.9) and short periods (in days): **7.31** (7.24), **8.40** (8.58), **12.4** (12.1), **15.7** (15.9), **16.1** (---), **40.2** (40.4), **58.4** (60.1), **62.1, 80.4** (80.4), **138.8** (140), **160.7** (161), **179.0** (183), **233.8** (---), **237.4** (237), **288.6** (285). Predicted periods of variations are pointed in parenthesis.

In accordance with general principles of developed mechanical approach (Barkin, 2002) a new planetary phenomenon of inversion of gravity variations in opposite hemispheres of the Earth must be observed. Relative translational displacements of core and mantle generate contrast variations in opposite hemispheres of the Earth. So, annual gravity variations in northern and southern hemispheres of the Earth are in anti-phase. Maximum of gravity in northern hemisphere and minimum of gravity in the southern hemisphere can be expected in Feb-March and contrast values in Aug-Sep.

1 Nature of cyclicity

Tidal effects. Full tidal effect on the Earth is presented as superposition of lunisolar and planet tides. These tides are described by the linear theory of elasticity. The tensional state of the Earth is characterized by the elastic energy due to the superposition of tides. We have shown that the Earth elastic energy of the tides is not additive sum of energies of separated tides due to concrete celestial body but contain additional crossed terms that can reach in some cases a magnitude similar to the classical terms associated to a sole body. They are caused by the simultaneous actions of the Moon and Sun or another pair of external celestial bodies including the planets. These additional terms can be significant and lead to remarkable periodic variations of elastic energy (Barkin, Ferrandiz, 2003). This effect is caused by quadratic structure of elastic energy and by geometry of Earth mantle deformations. We bring here final expression of elastic tidal energy of the Earth taking into account only second harmonic:

$$E = e_2 \left[\frac{m_M^2}{r_M^6} + \frac{m_S^2}{r_S^6} + 2 \frac{m_M m_S}{r_M^3 r_S^3} P_2(\cos S_{MS}) \right] \tag{1}$$

(m_M and m_S are the masses of Moon and Sun; r_M and r_S are corresponding distances between Earth center of mass and the Moon and the Sun consequently; $\cos S_{MS}$ is a cosine of the angle S_{MS} between geocentric directions to the Sun and to the Moon; P_2 is a polynomial Legendre of second order). Conditionally-periodic structure of the energy (1) is determined by corresponding properties of orbital motion of the Moon and the Sun. Cyclicities of orbital motion are reflected in variations of the elastic energy.

Elastic energy characterized by perturbed state of the Earth. Part of this energy dissipates and goes to an activation of different inner endogenous process including seismic and volcano processes. Variations of elastic energy depend from cyclic perturbations in orbital motion of the Moon and Sun and determine variations of mentioned processes.

Shell interaction effects. Gravitational attraction of the Moon and Sun side by side with tidal forces generates big additional mechanical forces (and moments) between the neighboring non-spherical shells of the Earth (rigid core, liquid core, mantle and its layers). These induced forces and moments are cyclic functions of time, which are changed in the different time-scales, due to cyclic properties of the unperturbed and perturbed orbital motions of external celestial bodies. They generate corresponding cyclic perturbations of the tensional state of the shells, their deformations, small relative translational displacements and slow rotation of the shells, formation of the planetary crack system, redistribution of the plastic and fluid masses, the planetary redistribution of the liquids and others. All these processes are cyclic. Their cyclic variations are observed in different time-scales. From the more important mechanisms of endogenous activity of celestial body (in particular of the Earth) we point out: 1) small relative rotation (nutations) of the shells in different time-scales; 2) small relative translational motions of the shells (displacements of their centers of mass); 3) relative displacements and rotations of the shells due to eccentricity of their center of mass positions. In geological time-scale discussed mechanisms give definite contributions to a cyclic tectonic reconstruction of the Earth (Barkin, 2002).

2 Perturbed shell interaction and rhythms of processes

For planets and satellites forced shell interactions have place between the core, mantle and others. For the Earth for example the giant forces are appeared between core and mantle, between

shells with boundary at 670 km, between lithosphere and separate plates. So additional cyclic force of mutual interaction of the liquid core and mantle (caused by the Moon attraction) is about 10^{-6} of gravitational force between Earth and Moon. This force is in a few orders bigger then classical tide force in the Earth-Moon system. The analytical expressions of the components of these forces in the inertial and in body reference system were obtained from differential equations of the relative translatory-rotary motion of two-shell model of planet in gravitational field of perturbing body. The module of additional force acting between shells is determined by formula (Barkin, 2002):

$$F(r,\gamma) = D\sqrt{1 - 2\gamma^2 + 5\gamma^4} / r^4, \qquad (2)$$

where r is a module of radius-vector $\bar{r}$ of the perturbing body (the Moon, the Sun) in geocentric reference system; γ is an angle between radius-vector $\bar{r}$ and a polar axis of inertia of the planet (Earth); D is a constant parameter depending from the mass of the shells and from their moments of inertia. The force (2) defines an intensity of the shell interaction, controls processes of variations of the tension state of the shells and dictates variations of natural processes into shells and on the planet surface.

In the case of circular orbit of perturbing body a force (2) will be a periodic function and can be presented in form of Fourier series. Periodic components of the force (2) will be changed with periods $T/(2i)$ $(i = 1,2,3...)$, where $T = 2\pi/n$ is a period of orbital motion of perturbing body. Here we obtain a confirmation for the known observed fact that periods of some cyclic variations of the concrete natural processes are connected by simple relation $T_i = 2T_{i-1}$. For real perturbed orbit the force (2) will be conditionally-periodic function of time with wide base of frequencies which will define corresponding variations of the natural processes.

3 Variations of the Earth, Moon and Sun processes and their unity

Very important conclusion follows from our approach. Natural processes are controlled and dictated by mentioned tidal mechanism and mechanism of shell dynamics and are subjected by cyclic variations with general base of frequencies. These basic frequencies are some combinations of the frequencies of the perturbed orbital motions of the Moon, the Sun and planets.

Table 1. General base of periods.

a) Short periods (in days)			b) Interannual and decade periods (in years)			
476 (471.9)	172 (173.3)	50.4	1.02	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)	1.83	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)	76.5		5.19	17.06	58.54	211.0
192 (193.6)	69.8		5.97	18.68	62.77	344.0
183 (182.6)	60.1		6.58	20.10	66.43	539.0

In result of analysis of the wide list of Earth's natural processes (Earth rotation, geocenter motion, base line variations for the VLBI stations, variations of seismicity of the Earth and the

Moon, magnetic field variations, ocean and atmosphere variations, climate variations, El Nino activity variations, bioproductivity variations and some others) we have determined the general frequency basis for the all Earth processes. Periods for these frequencies are presented in the Table 1a, b. The corresponding periods of some frequencies of the lunar orbital theory and their combinations are pointed in brackets.

Similar mechanism of shell dynamics works on the Moon and on the Sun. Orbital perturbations of the Earth and the Moon are characterized by the same frequencies. It means that the natural processes on these bodies are varied with general base of frequencies. These variations must be observed for many phenomena. Variations of the Earth rotation, variations of the geopotential coefficients, and gravity variations (at any gravimetric station on the Earth surface) are characterized by general base of frequencies.

Gravity variations. Predicted periods of variations of the natural processes were confirmed by results of the spectral analysis of various processes in nature and society. In particular periods from Table 1(and hypothesis about unity of natural processes) have obtained confirmation in observational data of gravity variations (at Moscow fidicial station), Earth rotation, vertical crust deformations (Kaftan, 2002). So, periods, amplitudes (in a few microGal) and phases for about 20 harmonics of gravity variations were determined in result of spectral analysis of the absolute gravimetric measurements. Interannual periods (in years): **1.03** (1.02)**, 1.58** (1.62), **2.49** (2.49), **6.00** (5.97), **10.7** (10.9) and short periods (in days): **7.31** (7.24), **8.40** (8.58), **12.4** (12.1), **15.7** (15.9), **16.1** (---), **40.2** (40.4), **58.4** (60.1), **62.1, 80.4** (80.4), **138.8** (140), **160.7** (161), **179.0** (183), **233.8** (---), **237.4** (237), **288.6** (285). Predicted periods of variations are pointed in parenthesis.

Variations of the load moment components. In paper Titov (2003) the characteristics of the all load moment components are determined. The spectral analysis of X, Y, Z components and complex parameter $X - iY$ have been fulfilled. In particular variations with periods (in years): 1.01 (1.02), 1.46 (1.41) and in days: 205 (206), 102 (100) and others were determined. In brackets we point corresponding predicted periods from the Table 1 a, b.

Cyclicities of the natural processes on the Sun and on the Earth. Here we present list of theoretical values of periods of cyclic variations of forced interaction of the Earth's shells due to Sun gravitational attraction. Same variations must be observed also in the Sun's shells interaction due to Earth's attraction. These values are obtained directly by formulae (2). The values are given in days:

182.6 , **91.3**, **60.9**, 45.7, 36.53, **30.44**, **26.9**, 22.83 , **20.29**, **18.26**, 16.60, 15.22, **14.5**, 13.05, 12.18, 11.41, 10.74, 10.14, 9.61, **9.13**, 8.70, 8.30, 7.94 , 7.61, **7.31**, **7.02**, **6.76**, 6.52, 6.30, 6.09, 5.89, 5.71, 5.53, 5.37, 5.22, 5.07, 4.94, 4.81, 4.68, 4.57, 4.35, 4.25, 4.15, 4.06 , 3.97, 3.89, 3.805, 3.727. Some remarked periods correspond to observed variations of the natural processes. Another variations (with periods from given list) will be discovered in future for many of natural processes.

Cyclicities of the natural processes on the Earth and on the Moon. In similar manner the Moon attraction also stimulates the Earth's shells in particular with periods (values given in days):
13.66, **6.83**, 4.55, 3.42, 2.73, 2.27, 1.95, 1.71, 1.52, 1.37, 1.24, 1.14, 1.05, 0.98, 0.91, 0.85. Variations with periods 13.66 days and 6.83 days in reality are observed in seismicity of the Earth and Moon and in solar activity. The real properties of the perturbed orbital motion of the Earth-Moon-Sun system produces a very wide list of the new rhythms of natural processes.

4 Inversion phenomenon of natural processes

In accordance with general principles of developed mechanical approach (Barkin, 2002) a new planetary phenomenon of inversion of gravity variations in opposite hemispheres of the Earth must be observed for many from natural processes. Relative translational displacements of core and mantle generate contrast variations of process activity in opposite hemispheres of the Earth. On

another hand observed phenomena of inversion of geoprocesses practically unequivocally testify to a reality of the mechanism of relative translational displacements of the Earth mantle and core. Observed displacements of the geocenter in definite rhythms give another confirmation of mentioned shell-mechanism (Barkin, 2001; 2002).

Prediction of inversion of secular change of gravity. From our studies it follows that due to secular displacement of the Earth core relatively center of mantle to southern direction (to the geography point 70^0S, 70^0W) must be observed following phenomena: secular axisymmetrical deformations of Earth surface along pointed geocentric axis and secular asymmetrical sea surface deformations (due to non-symmetrical positions of Earth continents). This phenomenon also follows from mechanical principals of developed approach. This predicted effect is small (with extreme values about -18 mkGall/century at Taymyr peninsula and +18 mkGall/century at Alexander I Earth) (Barkin, 2001) and in present can not be obtained from modern observations.

Inversion of annual gravity variation. Annual gravity variations in northern and southern hemispheres of the Earth (for same northern and southern latitudes) must be observed in anti-phase. Maximum of gravity in northern hemisphere and minimum of gravity in the southern hemisphere can be expected in Feb-March and contrast values in Aug-Sep. Expected amplitude is 3.8 mkGall. Confirmation to this hypothesis we find in data about annual gravity variations at Esashi and Canberra stations (Sato, Fukuda, Aoyama et al, 2001). Gravity changes at these stations are in anti-phase and extreme values fall on mentioned months.

Explanation of inversion phenomenon of Earth planetary deformations (annual and secular effects). Mentioned core-mantle displacements will generate asymmetrical deformations of the Earth mantle. The southern hemisphere of the Earth will be extended and opposite hemisphere will be contracted. Velocity of this secular change is very small and in present is not observed. But similar inversion of deformation field must be observed for periodic oscillations of the Earth shells (for example with annual period). And this phenomenon was detected on the base VLBI measurements for period 1996-2001 years (Lavallee, Blewit, 2002): "Maximum contraction within the northern hemisphere and maximum extension within the southern hemisphere occurs during northern hemisphere winter (Feb-March). The opposite deformations occur during southern hemisphere winter (Aug-Sep)". This phenomenon correlates with annual inversion of gravity.

Volcano activity inversion phenomenon. In our study an explanation of such difficultly interpretive phenomenon as increase of volcanic activity of subduction zones and decrease of same activity in spreading zones in last 100-120 years (Mekhtiev, Khalilov, 1987) was given. According to our results first of the specified zones mainly settle down in that hemisphere of the Earth to which last century there was a displacement of the Earth core. Increasing of volcanic activity in this hemisphere is connected with increasing of tension and with redistribution of fluids in higher layers of the Earth. Long periodic variations of volcano activity (with periods in a tens years) also are characterized by phenomenon inversion and can be explained in similar manner.

Sea level trend as consequence of inversion. Displacement of the Earth core relatively center of mantle to southern direction (to the geography point 70^0S, 70^0W) leads to asymmetrical deformations of ocean bottom and to secular ocean deformations. Last are characterized by non-symmetrical positions of Earth continents. Due to action of these two factors we observed in reality secular increasing of sea level. Gravitational and mechanical influence of moving core plays a main role for these variations (Barkin, 2001).

References

Barkin Yu.V.: 2001. Explanation and prediction of the secular variations of the Earth rotation, geopotential, force of gravity and geocenter drift. Proc. of intern. conf. «AstroKazan-2001». Astronomy and geodesy in new millennium (24-29 September 2001), KSU: Publisher «DAS», 2001, p.73-79.

Barkin Yu.V.: 2002. Explanation of endogenous activity of planets and satellites and its cyclicity. Izvestia cekzii nauk o Zemle. Rus. Acad. of Nat. Scien., Issue 9, M.: VINITI, pp. 45-97. In Russian.

Barkin, Yu.V., Ferrandiz, J.M.: 2003. Mechanisms of Earth activity forced by external celestial bodies: energy budjet and nature of cyclicity. EGS-AGU-EUG Joint Assembly (Nice, France 7-11 April 2003). Geophys. Res. Abstr., Vol. 5, 03227, 2003 © European Geophysical Society 2003.

Gamburzev A.G.:2002. Cycles and rhythms of natural proesses and atlas of temporal variations. Theses of conference " Rhythms and cyclicity in geology as reflection of general laws of evolution" (Feb. 7-8, 2002, Moscow), IPKON RAN, 13-15.

Kaftan V.I.: 2002. Gravity variation of the Moscow fiducial station. EUREF Publication. No. 10, pp. 293-296.

Lavallee D., Blewit G.: 2002. Degree-1 Earth deformation from very long baseline interferometry measurements. Geophysical research letters, Vol. 29, N 20, 1967.Sato T., Fukuda Y., Aoyama Y., McQueen H., Shibuya K., Tamura Y., Asari K., Ooe M.: 2001. On the observed annual gravity variation and the effect of sea surface height variations. Physics of the Earth and Planetary Interiors, V. 123, pp. 45-63.

Mehtiev Sh.,F., Khalilov E.N.: 1987. Reflection of geodynamic processes in space-time distribution of eruptions of volcanos of the world. Izv. AN Tadj. SSR, N2, pp. 65-70.

Sato T., Fukuda Y., Aoyama Y., McQueen H., Shibuya K., Tamura Y., Asari K., Ooe M.: 2001. On the observed annual gravity variation and the effect of sea surface height variations. Physics of the Earth and Planetary Interiors, V. 123, pp. 45-63.

Titov O.: 2003. Spectral analysis of the load moment components. Geophysical Research Abstracts, Vol. 5, 00888.