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# About possible polar drifts of centres of mass of the Earth and Mars

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**1 Drift of the centre of mass.** To determine a secular drift of the centre of mass of the Earth relatively to some mantle reference system, it is necessary to determine velocities of secular changes of three coefficients of the first harmonic of geopotential in this reference system: $\dot{C}_{11}$, $\dot{S}_{11}$ и $\dot{C}_{10}$. But for rough estimates of components of velocity of drift of the centre of mass in the certain terrestrial system of coordinates it is possible to take advantage of the following method [1]. In frame of model we admit, that in some initial epoch the planet had the spherical form, and in area of its North and South Poles of the beginning to be formed some "a tidal caps". This caps we shall model by a material point situated at northern pole $M+m$ and $-M$ at the southern pole. Masses of these points are increased linearly in due course $m=\dot{m}t$, $M=\dot{M}t$ with the constant velocities $\dot{m}$, $\dot{M}$. The numerical values of parameters of model were obtained on the base known observations about temporal variations of gravitational coefficients of Mars [2]. These values are given in Table 2. The fluid material of these caps is accumulated from all surface of a planet (thus the total mass of the Earth remains constant). In the certain sense here we have some analogue of an usual tidal bulges of the Earth. Let's assume that the specified redistribution of masses of the Earth is organized as a result of displacement of the core relatively to the viscoelastic mantle. Thus, full redistribution of masses represents redistribution of fluids and displacement of superfluous mass of the core. Both these of process bring the significant contribution to displacements of the centre of mass $C$. We shall note at once, that in relation to it initial position we can not determine a velocity of the point $C$ (on values of coefficients of the second and third harmonics of gravitational potential). We shall simplify a problem and we shall assume, that displacement of the core occurs along a polar axis of the Earth to the North, and the fluid cap is formed on the North Pole. Thus the Earth will be an changeable axysimmetric body with an axis of dynamic symmetry $Oz$. The origin of this axis coincides with the centre of "a spherical part of a planet". Coefficients of the second and third harmonics of a geopotential $J_2$ and $J_3$ will vary in time. And they are determined in geocentric reference system of coordinates $Cxyz$ with the origin in the centre of mass. An axis $Cz$ is the polar axis, and axes $Cx$ and $Cy$ are equatorial axes. We shall enter now into consideration a similar system of coordinates $Ox'y'z'$ with the origin in some special point $O$ and with axes parallel to the same axes of coordinates $Cxyz$. If coordinates of any elementary mass of the Earth $dm$ in systems of coordinates $Ox'y'z'$ and $Cxyz$ to designate, accordingly, $x, y, z$ and $x', y', z'$, between the last there are obvious relations: $z' = z_C + z$, $x' = x$, $y' = y$. Here $z_C$ is a value of coordinate $z$ of the centre of mass in system of coordinates $Ox'y'z'$. And now we shall assume, that the point $O$ is picked up in such a manner that the coefficient of the third zonal harmonic (in the system of coordinates $Ox'y'z'$) addresses in zero: $J_3' = 0$. From a condition $J_3' = 0$ it is uneasy to obtain the cubic equation for determination of polar coordinate of the centre of mass: $J_3' = J_3 + 3J_2 z_C / R - z_C^3 R^{-3} = 0$. The solution of this equation can be written down by the exact formula:

$$z_C = -2R\sqrt{J_2}\cos\left[\left(\arccos\left(J_3/\left(2\sqrt{J_2^3}\right)\right)-2\pi\right)/3\right]$$

or in the approached kind: $z_C = -RJ_3/(3J_2)$. Here $R = r_p$ is a mean radius of planet (Table 1). Under last formula we find the value of velocity of secular drift of the centre of mass relatively to the

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point $O$ [1]: $\dot{z}_C = -R\left[\dot{J}_3/(3J_2) - J_3\dot{J}_2/(3J_2^2)\right]$.

Table 1. Superflous masses of the cores of the Earth and Mars. Parameters of the planets, their cores and mantles.

| $P_p$ | Земля | Марс |
|---|---|---|
| $m_P$ | $59.736\cdot10^{23}$ kg | $6.4185\cdot10^{23}$ kg |
| $r_P$ | 6371.01 *km* | 3389.92 km |
| $r_c$ | 3480 km | 1750 km |
| $\rho_P$ | $5.515\ \mathrm{g/cm^3}$ | $3.933\ \mathrm{g/cm^3}$ |
| $\rho_m$ | $4.44\ \mathrm{g/cm^3}$ | $3.7\ \mathrm{g/cm^3}$ |
| $\rho_c$ | $10.98\ \mathrm{g/cm^3}$ | $6.3\ \mathrm{g/cm^3}$ |
| $\Delta\rho_c$ | $6.54\ \mathrm{g/cm^3}$ | $2.6\ \mathrm{g/cm^3}$ |
| $\Delta m_c$ | $11.54\cdot10^{23}$ kg $\approx 15.7\ m_{Moon}$ | $0.5837\cdot10^{23}$ kg $\approx 0.794\ m_{Moon}$ |
| $\Delta m_c / m_p$ | 0.1932 | 0.0909 |

Here $m_P$, $r_P$ and $\rho_P$ is the mass, mean radius and mean dencity of planet, $\rho_m$ and $\rho_c$ are the mean dencities of the mantle and the core; $\Delta\rho_c$ and $\Delta m_c$ is superflous mean dencity and corresponding superflous mass of the core. $r_c$ is a radius of the core.

We shall note, that this velocity in the given model depends only on values of coefficients of the second and third zonal harmonics of a geopotential and from their velocities of secular changes. In initial work on the given problem it was supposed, that the point $O$ corresponds to the centre of a figure of the Earth and is close to a geocenter. For values of these parameters given in Tables 1 and 2, we obtain preliminary (essentially overestimated) estimations of velocities of secular displacements of the centers of mass of the Earth: $\dot{z}_C = 2.6 \pm 1.0$ cm/yr and Mars: $\dot{z}_C \approx 2.3$ cm/yr.

**2 Polar drift of the Earth core.** It was shown, that polar drift of the centre of mass of the Earth is mainly determined by polar drift of the Earth core with its superfluous mass $\Delta m_{core} = 0.1932 \cdot m_E$ and for our first estimation $\dot{z}_C = 2.6 \pm 1.0$ cm/yr makes significant value $\dot{z}_{core} = 13 \pm 5$ cm/yr . This value is overestimated. Really, satellite observations of DORIS system give value of velocity of secular drift of the centre of mass of the Earth $\dot{z}_C = 5.2 \pm 0.4$ cm/yr [3]. On our geodynamic model this phenomenon first of all is connected to secular displacement of the centre of mass of the core relatively to the mantle in the direction of North Pole with velocity $\dot{z}_{core} = 2.6 \pm 0.3$ cm/yr . Nevertheless first of estimation of velocity of secular drift of the centre of mass (on character of change of the pear-shaped form of the Earth) has the important value. Its strictly determines a direction of drift of the centre of mass to the North and specifies the order of its velocity. Therefore we carry out similar constructions here with reference to other planet - to Mars [2].

Table 2. Velocities of change of masses of modeling points (models for the Earth and Mars).

| $P_p$ | Земля | Марс |
|---|---|---|
| $J_2$ | $1082.626075\cdot10^{-6}$ | $1.9557\cdot10^{-3}$ |
| $J_3$ | $-2.532516\cdot10^{-6}$ | $0.0333\cdot10^{-3}$ |
| $\dot{J}_2$ | $-(2.7\pm0.4)\cdot10^{-11}$ 1/yr | $\approx$ -$57.0\cdot10^{-11}$ 1/yr |
| $\dot{J}_3$ | $-(1.3\pm0.5)\cdot10^{-11}$ 1/yr | $\approx -4.94\cdot10^{-11}$ 1/yr |
| $\dot{m}$ | $(0.196\pm0.029)\cdot10^{15}$ kg/yr | $\approx 0.659\cdot10^{15}$ kg/yr |
| $\dot{M}$ | $-(0.039\pm0.037)\cdot10^{15}$ kg/yr | $\approx -0.257\cdot10^{15}$ kg/yr |
| $\dot{m}/m_p$ | $(3.28\pm0.49)\cdot10^{-11}$ 1/yr | $\approx 102.7\cdot10^{-11}$ 1/yr |
| $\dot{M}/m_p$ | $(0.66\pm0.62)\cdot10^{-11}$ 1/yr | $\approx -39.96\cdot10^{-11}$ 1/yr |
| $\dot{M}_N$ | $(0.157\pm0.066)\cdot10^{15}$ kg/yr | $\approx 0.402\cdot10^{15}$ kg/yr |
| $\dot{M}_S$ | $(0.039\pm0.037)\cdot10^{15}$ kg/yr | $\approx 0.257\cdot10^{15}$ kg/yr |

Here $J_2$ and $J_3$ are coefficients of the second and third zonal harmonics of gravitational potential of a planet, and $\dot{J}_2$ and $\dot{J}_3$ are their velocities of secular changes in present period. $\dot{m}$ and $\dot{M}$ are velocities of secular variations of the modeling masses located on a surface of a planet at its poles of polar axis.

**3 Possible polar drift of the Mars core.** On the basis of rough estimates of parameters of secular redistribution of fluid masses from a southern hemisphere in northern it was shown, that this redistribution can result to significant trend of the centre of mass of Mars in the northern direction with velocity of the order $\approx 3.5$ mm/yr . To one this effect there corresponds the polar drift of the centre of mass of the core of the Mars with velocity $\approx 3.9$ cm/yr . The estimation of velocity of secular drift of the centre of mass on the basis of model of change of pure-shaped form of Mars most likely is overestimated (as it was in case of

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the Earth) and makes $\approx 2.3$ cm/yr . Expected value of velocity of secular drift of the centre of mass can make $\approx 5 \div 10$ mm/yr . And it means, that displacement of the core of Mars causes a part of polar trend the centre of mass of Mars with velocity $\approx 1 \div 6$ mm/yr . And velocity of possible polar drift of the core of Mars can be appreciated as $\approx 1 \div 6$ cm/yr .

**4 Conclusion.** The fulfilled estimations of parameters of secular drift of the centre of mass of the Earth already have obtained reliable confirmations in various geosciences: at an explanation of observably variations of a gravity and geocentric heights, a global sea level, coefficients of a geopotential etc. (Barkin's reports at Vienna EGU GA in 2007-2009). The executed estimations for Mars are rather approached because of errors of base parameters of considered models. But they give a prediction of the important effect – the drift of the core of Mars to the North.

If this prediction will prove to be true in the future it will allow to reveal and confirm the whole sequence of the new geodynamic and geophysical phenomena on Mars: acceleration of Mars rotation, drift of the pole of rotation, secular variations of geopotential, increase of activity of natural processes, is especial in northern hemisphere, warming of a climate, slow growth of average atmospheric pressure in northern hemisphere and its decrease in southern, increase of a gravity in northern hemisphere and its decrease in a southern etc., i.e. those phenomena which are reliably established on the Earth.

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