EPSC Abstracts,
Vol. 4, EPSC2009-293, 2009
European Planetary Science Congress,

Secular variations of Martian processes, modeling of mass redistribution and prediction of pole drift and axial acceleration of Mars

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Resume. The certain analogy in secular variations of some natural processes on the Earth and on Mars is revealed. On this basis the assumption is made, that on Mars, as well as on the Earth, the mechanism of the forced swing and relative displacements of the core and the mantle which brings the essential contribution to observably redistribution of fluid masses of a planet actively proves. On the basis of rough estimates of values of velocities of secular variations of coefficients of the second and third zonal harmonics of gravitational potential of Mars the point model of the directed redistribution of masses of this planet, similar those for the Earth has been constructed, and parameters of possible secular drift of a pole of an axis of rotation of Mars and non-tidal acceleration of its axial rotation have been appreciated.

1 Secular variations of Mars processes. Some natural processes on Mars have slow tendencies of secular changes. Similar changes specify, for example, climatic changes. For example, Mars undergoing significant global warming: "For three Mars summers in a row, deposits of frozen carbon dioxide near Mars' south pole have shrunk from the previous year's size, suggesting a climate change in progress. Because a Martian year us approximately twice as long as an Earth tear, the shrinking of the Martian polar ice cap has been going on for at least six Earth years. The polar ice cap is shrinking at "a prodigious rate." (data of NASA). Possible trend change in masses of polar ice caps of Mars in its northern and southern hemispheres are illustrated on Fig. 1.

Attributes of secular variations of coefficients of gravitational potential are seen in given radio observations over space vehicles of this planet which regularly act and processed, since 1999. Possible secular trend values of coefficients of the second and third zonal harmonics and velocities of their changes are specified on Fig. 2.

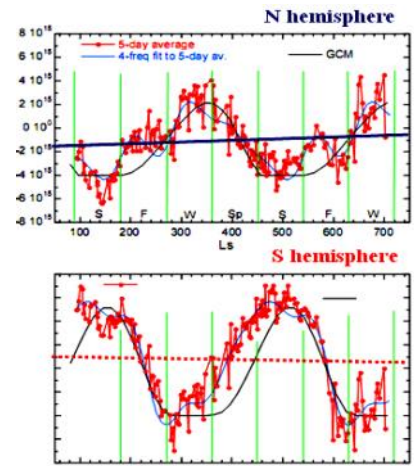

Fig. 1. Expected secular inversion changes of polar Mars ice caps (on data of Smith et al., 2008).

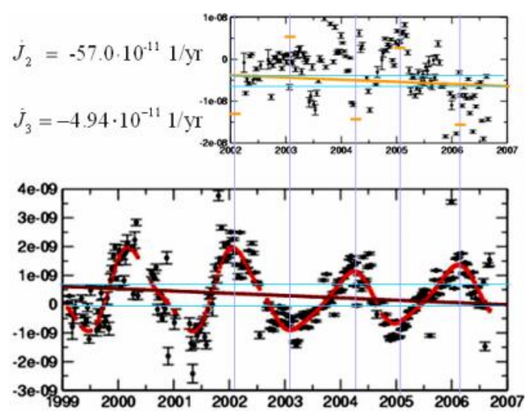

Fig. 2. Expected secular variations of the zonal coefficients J_2 and J_3 of gravitational field of Mars:

$\dot{J}_2 \approx -(10 \div 50) \cdot 10^{-11}$ 1/yr , $\dot{J}_3 \approx -(2 \div 5) \cdot 10^{-11}$ 1/yr .

On Dehant's materiales (Private communication, 2008).

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2 Modeling of mass redistribution. A vivid example for the similar phenomenon is Mars. Its center of mass is displaced relatively to the centre of figure on 3.3 km in the direction of pole P (64 N, 81 E). The figure of Mars is exclusively deformed because of gravitational displacement of the core (with superfluous mass about 1/10 mass of a planet) on rather significant distance about 25 - 30 km on a direction in region of pole P. The specified displacement is so great, that probably will be shortly accessible to detection from direct seismic experiments on the Mars. Similar research arises for studying of eccentric positions of the core of the Earth and the core of the Moon. For the Earth the specified displacement of the core can make some kilometres, and for the Moon tens kilometres. A prospective secular drift of the core of Mars to the North results in secular variations of its form, rotation and various planetary processes.

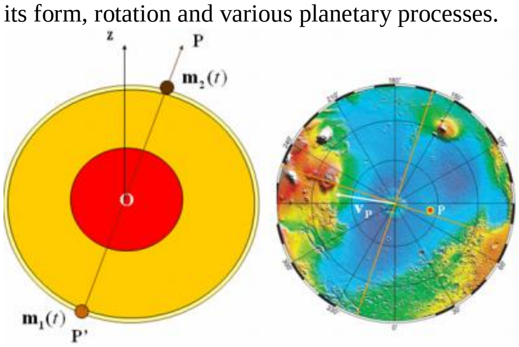

Fig. 3 Point model of directed redistribution of masses of Mars (left) and predicted direction of the drift of pole of axis of rotation of Mars (right).

Effective explanation of the pole drift of the Earth has been given by author on the base of so called point model of directed mass redistribution of planet [1]. Here we will show, that the similar model of the directed reorganization of masses of a planet (and about even big basis) can be applied to the Mars [2], [3].

On the geodynamic model [4] the observably constant displacement of the centre of mass of Mars relatively to its geometrical centre (on huge distance of 2.85 km in the direction of a geographical point 57^0 N, 82^0 E) there is a result of dynamic evolution of system the core – the mantle of this planet which can to proceed with the certain intensity and in present geological epoch.

I.e. by analogy to terrestrial processes we ascertain (we put forward a hypothesis), that on Mars is observed slow secular redistribution of fluid masses from a southern hemisphere in northern. As well as in the case of the Earth this process carries asymmetric, but strictly directed character. Such asymmetric slow redistribution of masses inevitably will result in secular variations of coefficients of gravitational potential of Mars, in particular in its coefficients of second and third zonal harmonics. The data available for today on variations of these coefficients basically already now allow to analyze these secular trends (more confidently for coefficient of the third harmonic J_3, and rather uncertainly for coefficient J_2). In the given work we use estimations (Fig. 2):

$$\dot{J}_2 = -57.0 \cdot 10^{-11} \text{ 1/cy} , \ \dot{J}_3 = -4.94 \cdot 10^{-11} \text{ 1/cy} .$$

On base of these values the secular variations of masses of modelling points (P, P', Fig. 3 left) located on a surface of Mars at poles of axis **OP** (with coordinates $57^0 N$, 82^0 E and $57^0 S$, 262^0 E) have been determined:

$$\dot{m}_1 = 0.257 \cdot 10^{15} \text{kg/yr} , \quad \dot{m}_2 = 0.402 \cdot 10^{15} \text{kg/yr} ,$$

$\dot{m}/m_P \approx 1.027 \cdot 10^{-9}$ 1/yr . Where $\dot{m} = \dot{m}_1 + \dot{m}_2$.

It is possible, that value of velocity $\dot{J}_2 = -57.0 \cdot 10^{-11}$ 1/yr is overestimated. Longer series of observations are necessary for its specification.

3 Pole drift of Mars. Therefore the estimations executed in the given work for parameters of drift of a pole and angular acceleration of axial rotation of Mars, are especially preliminary and can be considered as numerical evaluations or examples. These estimations turn out on the basis of known formulas for a components of pole drift of a deformable planet [5]:

$$\dot{p} = (1 + \omega / \Omega)\left(\dot{C}_{21}/I - \dot{P}/G\right)\omega ,$$

$$\dot{q} = (1 + \omega / \Omega)\left(\dot{S}_{21}/I - \dot{Q}/G\right)\omega .$$

Here $\dot{C}_{21}$ and $\dot{S}_{21}$ are velocities of secular changes of coefficients of gravitational potential C_{21} and S_{21}. $\dot{P}$ and $\dot{Q}$ are velocities of secular changes of components of angular momentum of relative motion of the fluids of a planet. Ω is a Chandler frequency, taking into account rotational deformations of elastic planet, and ω is an

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angular velocity of diurnal rotation of planet. $G=\omega C_0$ is an unperturbed value of angular momentum of rotation of Mars, C_0 is a polar moment of inertia. Components $\dot{p}$ and $\dot{q}$ determine drift of a pole relatively to the principal equatorial axes of inertia of a body in its non-deformed (or initial) state CX and CY. The appropriate components of the relative angular momentum $\dot{P}$ and also $\dot{Q}$ are referred to the specified axes. We have no any reliable data on secular variations a component of the angular momentum of all fluids of Mars. Therefore in the given work we shall be limited to estimations of influence only variations of geometry of mass:

$$\dot{p}/\omega \approx (1+\omega/\Omega)\left(\dot{C}_{21}/I\right) = -0''73 \, 1/\text{cy},$$

$$\dot{q}/\omega \approx (1+\omega/\Omega)\left(\dot{S}_{21}/I\right) = -5''2 \, 1/\text{cy}.$$

Variations $\dot{C}_{21}$ and $\dot{S}_{21}$ were calculated for considered point-model of secular redistribution of masses of Mars under formulas:

$$\dot{C}_{21} = \dot{m}\sin 2\varphi\cos\lambda/(2m_P) = 6.5\cdot 10^{-11} \, 1/\text{yr},$$

$$\dot{S}_{21} = \dot{m}\sin 2\varphi\sin\lambda/(2m_P) = 46.5\cdot 10^{-11} \, 1/\text{yr},$$

Thus, within the framework of the considered model problem we come to a conclusion, that drift of a pole of Mars can occur with velocity about $v_P = 5''3 \ 1/\text{cy}$ along meridian $98^0 0 W$ (with angular velocity approximately in 17 times higher, than at the Earth pole drift) (Fig. 3). It is possible, that this value is overestimated because of too big value of a variation of coefficient of the second zonal harmonic has been accepted here. But even in view of this feature it is necessary to expect rather significant effects, both in acceleration of daily rotation, and in drift of a pole of Mars. And it means, that the significant effects described above can be open directly from observations in the nearest years.

4 Non-tidal acceleration of Mars. The constructed model has allowed to estimate non-tidal acceleration of axial rotation which as it would be possible to expect, essentially surpasses the similar characteristic of rotation of the Earth. The obtained result means, that angular velocity of Mars in present period increases on the law $r = (0.70882180\mathbf{8000} + 0.00000000\mathbf{1038}\cdot t)\cdot 10^{-4} \, 1/\text{s}$, here t - in years. It is possible assume that the estimation of acceleration can be obtained directly on the basis of the data of observations in the nearest years. Velocity of secular change of duration of day for Mars (LOD) thus can make significant value about -0.0903 ms/yr, that considerably surpasses similar value for non-tidal acceleration of the Earth (-0.006 ms/yr). The ratio of positive acceleration of the Earth rotation $\dot{r}$ to its angular velocity ω makes $\dot{r}/\omega = (6.9\pm 1.7)\cdot 10^{-11} \, 1/\text{yr}$ [1]. In case of Mars the estimation of acceleration was carried out under the formula [4]:

$$\dot{r}/\omega = -\dot{C}/C - \dot{R}/G \approx -\dot{C}/C = 103.8\cdot 10^{-11} \, 1/\text{yr}.$$

We here have neglected by an influence of secular change of the axial angular momentum of fluid masses (atmospheric and underground) of Mars $\dot{R}$.

The work partially was financially supported by RFBR grant N 08-02-00367.

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