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Explanation of observable secular variations of gravity and alternative methods of determination of drift of the center of mass of the Earth

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The summary. On the basis of geodynamic model of the forced relative displacement of the centers of mass of the core and the mantle of the Earth the secular variations of a gravity and heights of some gravimetry stations on a surface of the Earth have ben studied. At the account of secular drift of the center of mass of the Earth which on our geodynamic model is caused by the unidirectional drift of the core of the Earth relatively to the mantle, the full explanation is given to observable secular variations of a gravity at stations **Ny-Alesund** (Norway), **Churchill** (Canada), **Medicine** (Italy), **Sayowa** (Antarctica), **Strastburg** (France), **Membach** (Belgium), **Wuhan** (China) and **Metsahovi** (Finland). Two new methods of determination of secular drift of the center of mass of the Earth, alternative to classical method of a space geodesy are offered: **1)** on the basis of gravimetry data about secular trends of a gravity at the stations located on all basic regions of the Earth; **2)** on the basis of the comparative analysis of altimetry and coastal data about secular changes of sea level also in basic regions of ocean.

1. Secular drift of the center of mass of the core and the center of mass of the Earth. A secular drift of the center of mass of the Earth to the North relatively to special center ***O*** on an axis of rotation of the Earth for which the coefficient of third zonal harmonic $J_3' = 0$, has been predicted in the author work [**1**]. A drift in a direction to a geographical point (pole P) 70º0 N and 104º3 E has been established for the first time theoretically - as a result of the analysis of the global directed redistribution of masses of the Earth, explaining the observed secular drift of the pole of an axis of rotation of the Earth and not tidal acceleration of its axial rotation [**2**]. In [**1**] velocity of drift it has been estimated in **1-2** cm/yr. For specified center ***O*** the figure of a planet is as though deprived of pure-shaped form ($J_3' = 0$). And in this sense the point ***O*** can be conditionally corresponded to the geocenter of the Earth approximately determined by position of stations of satellite observations, as the center of certain mantle systems of coordinates $Oxyz$. For an explanation of such significant drift of the center of mass of the Earth the mechanism of the unidirectional displacement of the core of the Earth (and its center of mass) relatively to a viscoelastic mantle [**1**, **2**] has been offered. The next years attempts of determination of velocity of secular drift of the center of mass in the mantle reference frame by methods of a space geodesy on the basis of precision satellite observations were repeatedly undertaken. In our work [**3**] for determination of a trend of the center of mass the data of the International Service of Rotation of the Earth (**IERS**) for satellite observations of system **DORIS** have been used. For components of velocity of drift in geocentric Greenwich system of coordinates for period 1999-2007 estimations have been obtained: on coordinate **x) -1.46** mm/yr, **y) 0.79** mm/yr and **z) 5.29** mm/yr (errors of the specified estimations make 5-10 %). The velocity of trend of the center of mass of the Earth and its direction are characterized by values: **5.54** mm/yr; latitude **72º6** ***N*** and a longitude **118º4** ***E***. The direction of displacement of the center of mass will well be coordinated with a direction predicted earlier theoretically [**2**]: latitude **70º** ***N*** and a longitude **104º** ***E***. We shall emphasize, that observable redistributions of superficial masses of the Earth explain only small part of observable displacement of the center of mass. It testifies in favour of a reality of secular relative displacement of the core and the mantle of the Earth.

2 Secular drift of the core to the North and variations of a gravity on the Earth surface. The displaced core of the Earth is characterized by the large superfluous mass approximately in **16.7** masses of the Moon. The superfluous mass is ditermined by contrast values of average densities of the core and the mantle and makes **19.32 %** of mass of full the Earth. At displacement of the core relatively to the viscous-elastic mantle its superfluous mass causes observable drift of the center of mass, and also leads to changes of a gravity on the surface of the planet. Except for it the gravitational attraction of a displaced core causes deformations of all layers of the mantle, including a superficial layer. The deformed mantle produses some additional gravitational potential which gives the additional contribution to value of a gravity. Thus, noted factors lead to a secular variation of a gravity which is described by the simple formula [**2**]:

$$\dot{g} = 2g\frac{\Delta m_c}{m_\oplus}(1 - h_{-2} - 0.5k_{-2})\frac{\dot{\rho}}{r_\oplus}\sin\Theta, \quad \Delta m_c = 0.1932m_\oplus, \quad g = 9.82022\ m/s^2 \qquad (1)$$

Here $\Delta m_c = 0.1932m_\oplus$ is a superflous mass of the Earth core in the masses of the Earth $m_\oplus$. g is an acceleration of free falling. k_{-2} and h_{-2} are Love numbers of the order (-2). $\dot{\rho}$is a velocity of the secular drift of the center of mass of the core relatively to the center of mass of the mantle. $\Theta$is an angle between dirtection to the pole ***P*** (in a direction to which the core of the Earth or its center of mass drifts), and direction to gravimetric station. For rough estimates of gravimetric effects as pole ***P*** the North Pole of the Earth has been accepted. Thus $\Theta = \pi/2 - \varphi$is a co-latitude. At more exact description of the core drift (or the center of mass drift) an angleΘ is determined by formula: $\cos\Theta = \cos\varphi_P\cos\varphi\cos(\lambda_P - \lambda) + \sin\varphi_P\sin\varphi$, where φ_P and λ_P is a latitude and longitude of pole ***P***; φ and λ is a latitude and longitude of station. The Love numbers of the order (-2) in first have been evaluated in the paper [**4**] and have small values: k_{-2}**=-0.005004** and h_{-2}**=0.0062154**. Approximately we can put $\dot{\rho}m_\oplus = \Delta m_c\dot{r}_C$, where $\dot{r}_C$ is a velocity of the drift of the center of mass of the Earth. Then, neglecting small effects, for a variation of gravity (1) we obtain a following expression:$\dot{g}_r = 2\dot{r}_C g\cos\Theta/r_\oplus$. Leaning on results of works [**2**], [**3**], we shall accept the following values of parameters of drift of the center of mass: $\dot{r}_C$**=5.54** mm/yr, φ_P**=70º0 *N***, λ_P**=104º3 *E***. On the other hand a displacement of the center of mass of the Earth leads to effect of slow change of heights of gravimetric station: $\dot{h} = -\dot{\zeta}_C\cos\Theta = -5.54\cdot\cos\Theta$ mm/yr. Errors in determination of the specified characteristics in the given work we shall neglect. Besides the gravitational attraction of a displaced core leads also to effect of increase of horizontal component of gravitational force of an attraction of the Earth on its surface directed to the North along the corresponding meridian with pole ***P***. For any point of a surface of the Earth this component of force is determined by the formula $\dot{g}_\varphi = \dot{r}_C g\sin\Theta/r_\oplus$ and has positive values. And the maximal values $\dot{g}_\varphi$ are reached on equator, which plane is orthogonal to axes of drift of the core ***OP***. Thus, final working formulas for studying of secular variations of components of force of a gravitational attraction of the Earth and for a variation of the heights caused by a drift of the center of mass of the Earth become: $\dot{g}_r = 1.74\cos\Theta/r_\oplus$ μGal/yr, $\dot{g}_\varphi = 0.87\sin\Theta/r_\oplus$ μGal/yr, $\dot{h} = -5.54\cos\Theta/r_\oplus$ mm/yr. Calculated values of mentioned gravimetric characteristics (2) for the wide list of gravimetry stations are resulted in work [**5**] and used in the given work.

3 Explanation of observable secular variations of a gravity and heights on gravimetric stations. We have been analysed observed variations of a gravity and heights available and accessible to us, namely their secular changes, for 8 known gravimetry stations. The periods of observations at mentioned stations make the order of 5-10 years, i.e. are not greater, but nevertheless the obtained results unequivocally testify in favour of that the basic contribution to secular variations of a gravity gives the drifting core of the Earth (by means of direct gravitational influence and due to a contribution to corresponding variations of heights). In the given work we did not consider other factors influencing on gravimetric measurements (superficial redistributions of fluid masses, variations of coefficients of the second and higher harmonics of a geopotential, etc.). As an example here we shall analyse secular variations of a gravity and heights at Ny-Alesund station (geographical coordinates: **78º93 *N***, **11º87 *E***, Θ =**23º16**). Linear trends of a gravity and height observable at this station make **-2.5**$\pm$**0.9** μGal/yr and **+ (6.9**$\pm$**0.9)** mm/yr, accordingly, during 1998-2002 (Sato et.al., 2006). On our model a slow closing of the core to the Ny-Alesund station causes a positive variation of a gravity in **1.60** μGal/yr and a negative variation of height of station in **-5.09** mm/yr [**5**]. These data testify a deformation of a surface of the Earth in area of station with a velocity **+11.99**$\pm$**0.9** mm/yr owing to which the gravity tests a negative variation **-3.74**$\pm$**0.28** μGal/yr. Putting effects of a variation of a gravity because of displacement of the core and from deformation of a surface, we obtain negative value for secular trend of gravity in **- (2.14**$\pm$**0.28)** μGal/yr, that within the limits of errors it will be coordinated with observable value **- (2.5**$\pm$**0.9)** μGal/yr. Similar results we have obtained for 7 another's gravimetric stations. All results are summarized in the table 1. Here we have used known data about observable secular trends of gravity and GPS heights at considered here stations of the following authors: **Ny-Alesund** (Sato et al., 2006); **Churchill** (Larson et al., 2000); **Medicine** (Zerbini et al., 2001); **Syowa** (Fukuda et.al., 2007); **Strastburg** (Almavict et. al., 2004); **Membach** (Francis et al., 2004); **Wuhan** (Xu et al., 2008); **Metsahovi** (Gitlein et. al., 2009).

Table 1. Theoretical and observable values of secular variations of a gravity.

Stations	Core attraction	Surface deformation	Theory	Observations
Ny-Alesund	**+1.60** μGal/yr	**-(3.77±0.09)** μGal/yr	**-(2.17±0.03)** μGal/yr	**-(2.5±0.9)** μGal/yr
Churchill	**+1.11** μGal/yr	**-(3.38±0.28)** μGal/yr	**-(2.22±0.28)** μGal/yr	**-(2.13±0.23)** μGal/yr
Medicina	**+1.13** μGal/yr	**+(1.07±0.20)** μGal/yr	**+(2.20±0.20)** μGal/yr	**+(1.90±0.20)** μGal/yr
Syowa	**-1.44** μGal/yr	**+(0.63±0.08)** μGal/yr	**-(0.81±0.08)** μGal/yr	**-0.56** μGal/yr
Strastburg	**+1.18** μGal/yr	**+(0.71±0.02)** μGal/yr	**+(1.89±0.02)** μGal/yr	**+(1.90±0.20)** μGal/yr
Membach	**+1.21** μGal/yr	**-(1.98±0.16)** μGal/yr	**-(0.77±0.16)** μGal/yr	**-(0.6±0.1)** μGal/yr
Wuhan	**+1.34** μGal/yr	**-(0.17±0.05)** μGal/yr	**+(1.17±0.05)** μGal/yr	**+(1.39±0.02)** μGal/yr
Metsahovi	**+1.47** μGal/yr	**-(2.82±0.06)** μGal/yr	**+(1.35±0.06)** μGal/yr	**-(0.88±0.52)** μGal/yr

4 Alternative methods of determination of drift of the center of mass of the Earth. In the work two new methods of determination of velocity of the secular trend of the center of mass of the Earth, based on gravimetric measurements and on the basis of altimetry and coastal measurements of sea level of ocean are offered for discussion. I.e. represents the important interest a inverse problem about determination of parameters of drift of the center of mass of the Earth on gravimetric measurements on the global system of stations. Alongside with the basic satellite method of determination of drift of the center of mass the specified method allows to execute independent determinations of velocity of drift of the center of mass and a direction of this drift in corresponding mantle reference frame. Other independent method of determination of drift of the center of mass is based on the comparative analysis of altimetry and coastal measurements of sea level in various areas of ocean in view of variations of heights of stations of observations.

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