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Vertical Stability of the Earth Inner Core

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Abstract

Vertical moments balance – stability (in the plane normal to the ecliptic) of the Earth solid inner core is analyzed. The most important influence comes from the shape of it. Both real rotation conditions around the Sun and itself push rotation axes of the core vertically "up" for the eccentricity coefficient (ratio between the equator and polar radiuses) bigger then 1.000000358. In all other cases gyroscope moment rotate the core vertically "down". Deformations of the solid inner core are analyzed by the finite element method relative to the centrifugal forces coming from the self – rotation and opposite compression forces caused by the gravity pressure. Resultant loads give the deformations adequate to the eccentricity of 0.9976, close to the shape of an egg. The rest liquid part of the planet with the opposite "sunny" moment and the shape of an ellipsoid give the reaction to the expected motion of the core via viscous friction, for now. Corresponding decreasing of the intensity of the Earth magnetic field probably means slowing down of the angular rotation of the core. The vertical sliding between inner core and the rest part of the planet could occur at one moment, causing magnetic and mechanical polar shift. The existing self – rotation of the inner core doesn't stop, affecting new sunrise on the west. The biggest probability for this event is related to the position of the planet with the biggest velocity in the sharpest part of its path curvature. It means in December every year. Mathematical analysis of the total intensities of the Earth magnetic field diagrams gives 2012 year.

Introduction

The use of the existing mathematical and mechanical tools for the analysis of the vertical (in the plane normal to the ecliptic) stability of the Earth solid inner core is easy and precise, what couldn't be told for the rest liquid or semi-liquid parts of the planet. That is why such calculation is done here, under next assumptions:

- material is iron (plus nickel) with the Young modulus of elasticity of 3.444E17 N/km^2, taken to be in the same ratio with the steel as their densities (1.28E13 kg/km^3 for core)
- Poisson's ratio is 0.3
- the radius of the ball is 1228 km
- angular velocity is the same as for the planet, 7.272E-5 1/s
- gravity pressure on the inner core is 3E17 N/km^2
- only two significant vertical moments influenced by the rotation of the planet around the Sun and itself are taken into account (all other, such as, for example, nutations coming from the Moon, are neglected)
- corresponding axes of the Earth and the Sun are in the same plane, with the angle between them of 23.5°
- the most characteristic position of the planet with its the biggest velocity and the smallest distance to the Sun 1.47E11 m in the sharpest curve (December every year) is analyzed (Figure 1)

In accordance with Coriolis Effect force components normal to the axis of the Sun appear (Figure 2).

The only interesting components (projections) are in the mentioned plane. The other components in the plane normal to this are balanced giving zero values. The moments related to center O, provided by these forces, trend to erect-right battered core axis to take the same direction as the Sun one. Resultant, so called "sunny" positive moment (+), enforces core to nullify its inclination related to the ecliptic.

So, in accordance with famous dynamics relations each part of the inner core is affected by Coriolis forces

$$dF = dm \bullet 2v\Omega \quad (1)$$

where are m – mass of the part, v – part velocity and Ω – angular velocity of the Earth around the Sun.

Because the mass could be expressed via density and volume

$$dm = \rho dV, \text{ namely} \quad (2)$$

$dm = \rho rd\beta rd\delta dr = \rho r^2 drd\beta d\delta$, in accordance with Figure 3,

where are δ angle in the direction of own rotation of the core, part velocity

$$v = \omega r\cos\beta \quad (3)$$

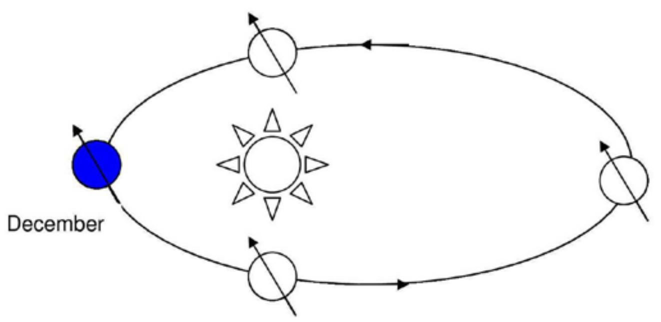

Figure 1:

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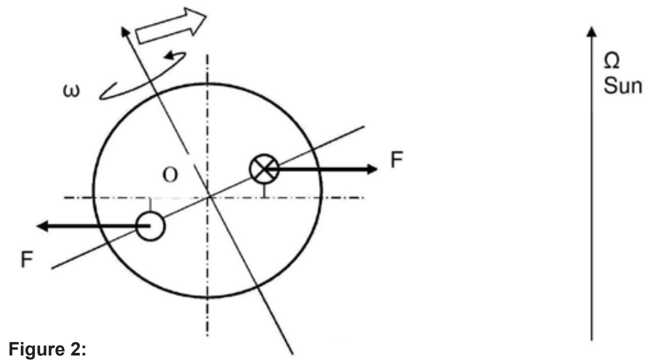

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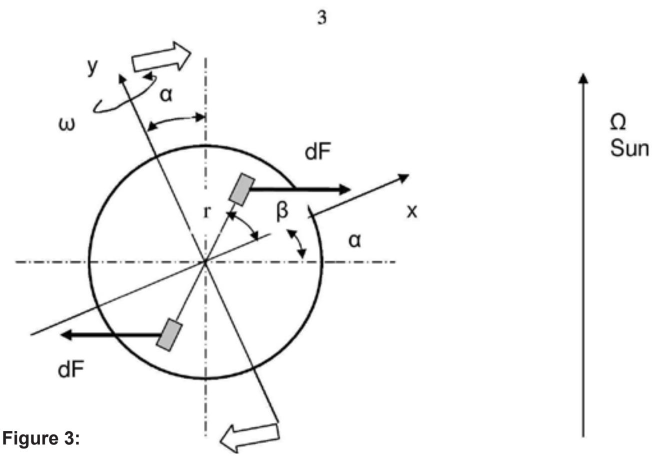

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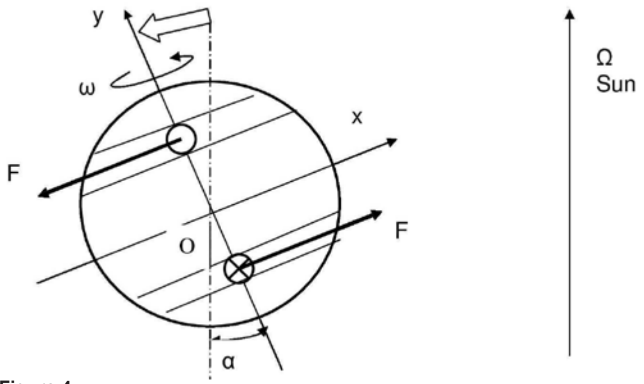


Figure 4:

ω - own angular velocity of the core, Coriolis forces obtain next form

$$dF = \rho r^2 dr d\beta d\delta \bullet 2\omega r \cos\beta \cos\delta \Omega \quad (4)$$

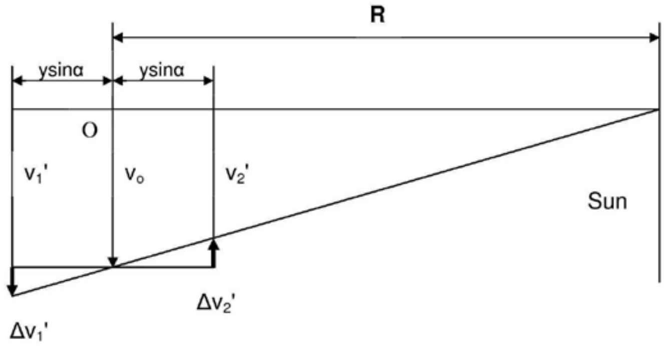
Corresponding moment acting to erect-right the core is then

$$dM^S = dF \bullet r \sin(\alpha+\beta)\cos\delta \quad (5)$$

apropos, after arrangement,

$$dM^S = 2\pi\rho/R \bullet (\gamma M_S/R)^{0.5} \bullet \{2\omega S^5 \cos\beta/5\pi + (\gamma M_S/R)^{0.5} \bullet [S^5\cos(\alpha+\beta)/5R - 2R^4/\cos^4(\alpha+\beta)$$

$$\bullet (\Gamma(1-\Gamma^2+3/5\Gamma^4-1/7\Gamma^6) - 16/35) - S^4/4]\}\sin(\alpha+\beta)d\beta, \quad (6)$$



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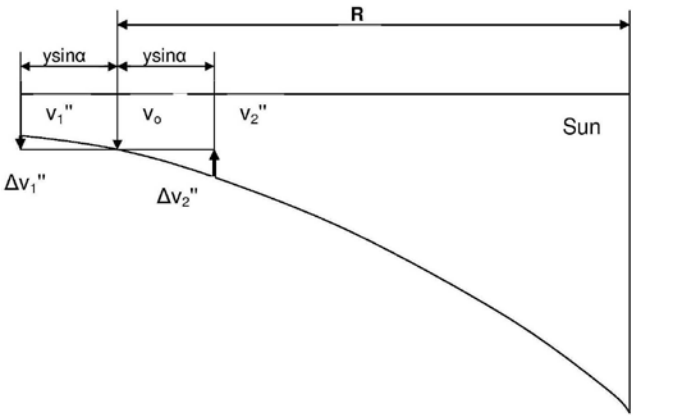

Figure 6:

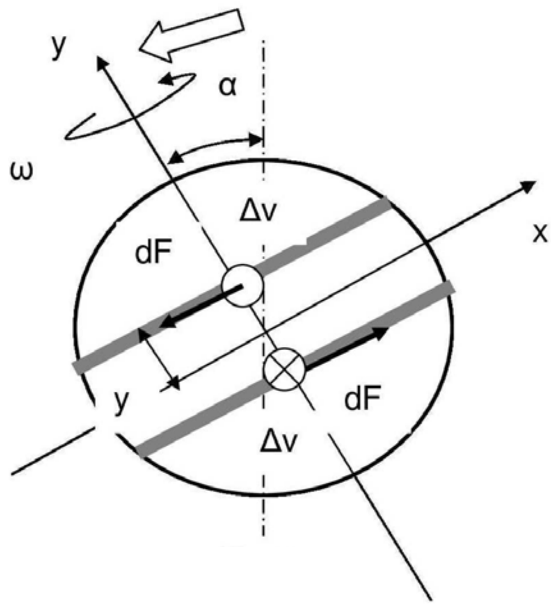

Figure 7:

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where are R – distance between the Earth and Sun, M_S – mass of the Sun, γ – constant of the gravity, and

$\Gamma = [1\text{-}S\cos(\alpha+\beta)/R]^{0.5}$, $S = B/A$, $B = ab$, $A = (a^2\sin^2\beta+b^2\cos^2\beta)^{0.5}$ and a and b radiuses of the ellipsoid. (7)

The results are obtained by numerical integration.

It should be underlined that the core is not material point in this analysis but a huge 3D rigid body, with all the consequences following the approach. It means officially calculated tangential velocity of the Earth (core) around the Sun is related to only one point of the rotation axis of the big bowl, to its center O, at this moment. All other points of the axis have different velocities. The points further from the center O, and from the axis of the Sun, precede, causing major velocities. In accordance with this all the points near the axis of the Sun have the smaller ones (Figure 4).

Corresponding effect of the circular motion of the rigid body could be expressed in the next way:

Proportions give real velocities of the single points of the core

$$v_1\text{'}: (R+y\sin\alpha) = v_o: R \rightarrow v_1\text{'} = v_o(1+y\sin\alpha/R) \quad (8)$$

$$v_2\text{'}: (R-y\sin\alpha) = v_o: R \rightarrow v_2\text{'} = v_o(1-y\sin\alpha/R) \quad (9)$$

and their discrepancies relative to the only analyzed velocity in the center of the core vo

$$\Delta v_1\text{'} = v_o(1+y\sin\alpha/R)-v_o = v_o y\sin\alpha/R \quad (10)$$

$$\Delta v_2\text{'} = v_o(1-y\sin\alpha/R)-v_o = -v_o y\sin\alpha/R \quad (11)$$

Existed precedence of the core points further from the Sun compare to the point O is heightened by the fact that orbit motion law is not linear. These parts additionally precede in their bustle relative to the necessary average velocity providing the planet path. The other points retard, more than accelerated ones. So, in accordance with Figure 6.

$$\Delta v_1\text{''} = v_o - [\gamma M_S/(R+y\sin\alpha)]^{0.5}; \Delta v_2\text{''} = v_o - [\gamma M_S/(R-y\sin\alpha)]^{0.5} \quad (12)$$

$$\Delta v_1 = v_o y\sin\alpha/R + v_o - [\gamma M_S/(R+y\sin\alpha)]^{0.5} \quad (13)$$

$$\Delta v_2 = v_o y\sin\alpha/R + v_o - [\gamma M_S/(R-y\sin\alpha)]^{0.5} \quad (14)$$

The resultant increments of the parts velocities of the core are then

$$\Delta v_1 = (1+y\sin\alpha/R)(\gamma M_S/R)^{0.5} - [\gamma M_S/(R+y\sin\alpha)]^{0.5} \quad (15)$$

$$\Delta v_2 = (y\sin\alpha/R-1)(\gamma M_S/R)^{0.5} + [\gamma M_S/(R-y\sin\alpha)]^{0.5} \quad (16)$$

The difference is not big but it is enough to provide another famous effect in dynamics. These velocity increments, directed to as from the plane of the paper for the axis part further then the point O, and with opposite direction for the axis part near the Sun, together with existed own rotation of the core, make gyroscope moment trying to “down” it. That moment, with applied sign -, tend to do something opposite compare to the “sunny” moment: to rotate battered rotation axis of the core to another direction to increase its inclination to ecliptic.

In accordance with famous dynamics relationships shadowed part

TOTAL INTENSITIES OF THE EARTH MAGNETIC FIELD			
	Hermanus	Hartebeesthoek	Tsumeb
Year	nT	nT	nT
2005.5	26027	28446	29835
2006.5	25984	28439	29809
2007.5	25945	28435	29791

Table 1:

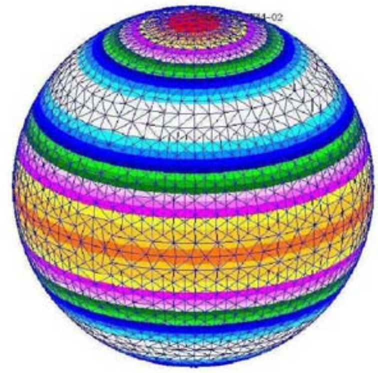

Figure 8:

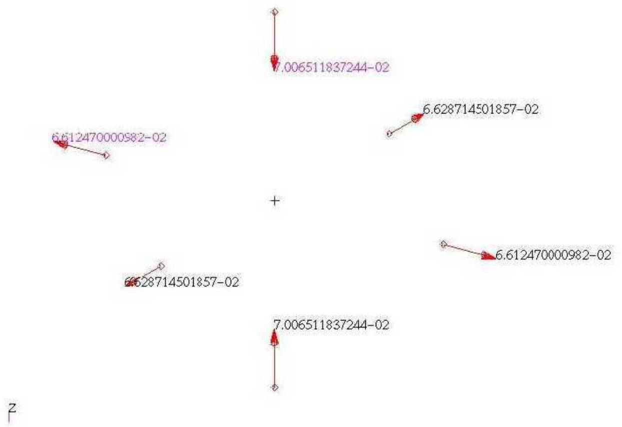

Figure 9:

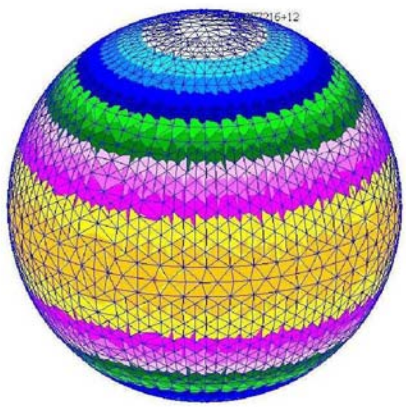

Figure 10:

of the core (Figure 7) is attacked by Coriolis forces

$$dF = dm \bullet 2\Delta v\omega \quad (17)$$

Onward it is

$$dm = \rho dV = \rho\pi x^2 dy \quad (18)$$

apropos

$$dF = \rho\pi x^2 dy \bullet 2\Delta v\omega \quad (19)$$

Corresponding moment trying to down the core is

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$$dM^Z = dFy \quad (20)$$

After arrangement the values get next form

$$dF^Z = 2\pi\rho\omega(a^2-a^2y^2/b^2)\cos\alpha\{[\gamma M_S/(R-y\sin\alpha)]^{0.5}+[\gamma M_S/(R+y\sin\alpha)]^{0.5}-2(\gamma M_S/R)^{0.5}\}dy \quad (21)$$

$$dM^Z = 2\pi\rho\omega(a^2-a^2y^2/b^2)y\{[\gamma M_S/(R-y\sin\alpha)]^{0.5}-[\gamma M_S/(R+y\sin\alpha)]^{0.5}+2y\sin\alpha(\gamma M_S/R)^{0.5}/R\}dy \quad (22)$$

The results are obtained by the numerical integration.

There are two opposite, crucial, vertical moments. The other ones are not so powerful and not interesting for this analysis. Look at the results. They are practically equal at the first sight, what should be in a good accordance with existed situation: the Earth doesn't rotate around horizontal axis. However, more precise analysis shows small differences in some solutions. Sometimes "sunny" moment is slightly bigger, and sometimes it happens with gyroscope moment.

The influence of several the most important factors effecting the moments is analyzed. Increase of the angular velocity of the core (Diagram 1) enlarges the intensity of both moments (upper line), and what is more interesting, the difference between them (bottom line) with the value exponent of 17 in benefit of gyroscope moment.

Increase of the distance between Earth and Sun (Diagram 2) causes decrease of both moments (upper line) and their difference (bottom line). Dominant gyroscope moment loses its importance and difference value exponent is the same as in the previous case, 17.

In the case of an increase of the rotation axis inclination (Diagram 3) some significant balance problems could appear. Difference value exponent remains the same, 17.

Two common components related to previous analysis could be underlined. The differences of the moments always give priority to gyroscope moment, and they are on the same levels of the values (exponent 17).

But, analyzed core is not absolutely rigid body. Centrifugal forces caused by its selfrotation could deform it making an ellipsoid. Increase of the angular velocity should enlarge eccentricity (ratio between equatorial and polar radiuses) of the core and vice versa. Of course, contra-ellipsoid, in the shape of an egg, could be imagined too. That is why adequate analysis is done (Diagram 4) to give corresponding answers. Upper lines show behavior of the vertical moments in the function of the eccentricity. Increase of the eccentricity cause increase of the "sunny" moment and decrease of the gyroscope moment – significantly. The difference is on the same level of the values as the moments. Corresponding exponent is 23. Million times bigger than in the previous cases. It means this phenomenon is the most authoritative for the extension of the analysis. That is why the attention is paid to it.

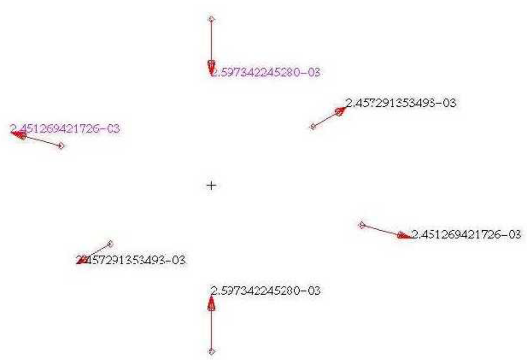

Figure 11:

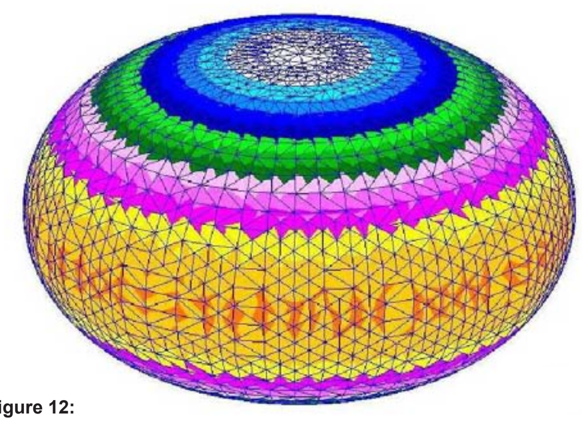

Figure 12:

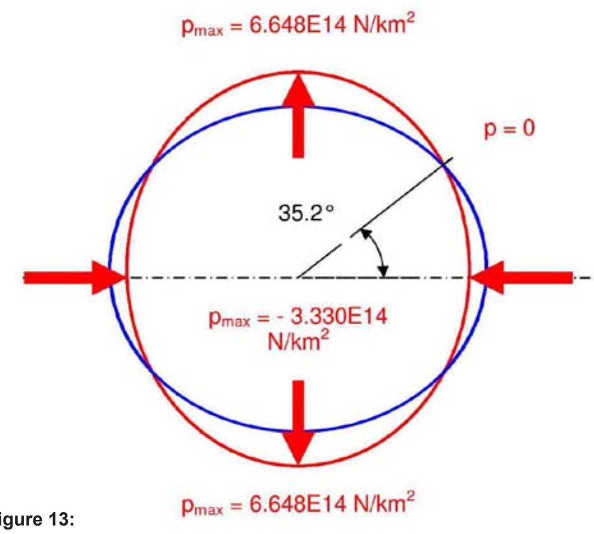

Figure 13:

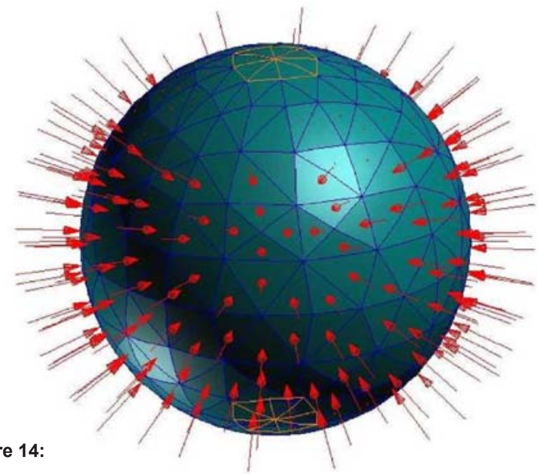

Figure 14:

Possible changes of the own angular velocity of the core deform its shape and so crucial affect the balance or predominance of the opposite moments. Faster rotation and bigger deformation give the chance to the "sunny" moment to nullify its inclination related to the ecliptic. Slow rotation and smaller deformations could allow the gyroscope moment to "down" it. Something similar to the top spin.

It could be found in the data that angular velocity of the Earth is decreasing: for example 0.0017 seconds per 100 years. Another reference related to the Earth magnetic field shows its impressive decrease of 10% for the last 150 years. Having in mind relation between this field and rotation of the inner core (dynamo effect) indirect reasonable argument regarding significant slowdown of the core spin could be done. Official statement related to the same (or mostly the same) angular velocities of the Earth and the core is not in a good accordance with mechanics. Such conclusion is justified only in the case of the rigid body, what the Earth is not. It seems the core slows down mo intense then the crust.

On the base of both relations, eccentricity of the core to provide equal "sunny" and gyroscope moments is found. It is 1.000000355. Such procedure is repeated for different angular velocities, giving different balance eccentricities, and for different distances of the planet from the Sun. The refractions of the curves around the value of 1.000000356 could be seen in Diagram 5. It is interesting that the curves don't cross the value of 1.000000358. We have vertical asymptote. It means the ellipsoids classified on the right side of the asymptote are stable and, contrary to it, left sided forms can't keep upright position.

The estimation related to the eccentricity of the inner core is done. Attractive and reliable finite element method, capable to solve complex problems in many complicated structures, is used here. The input data are given at the beginning of the article. Angular velocities problem could be solved by the analysis of expanded range of possible values, starting with that corresponding to the planet, 7.272E-5 1/s, up to some covering the some velocity of the fluid on the all altitudes, 3.777E-4 1/s, calculated on the base of the Earth and core radiuses. In both of the extreme cases eccentricities are over critical value: the smallest analyzed angular velocity provoke rise of the equator radius for 2.45 m and decrease of the polar one for 2.60 m, with the eccentricity of 1.000004114, whence the biggest one elongate and shorten them for 66.21 m and 70.07 m, providing eccentricity of 1.000110976. It should be underlined that the deformations are proportional to the squares of the angular velocities (Figure 8, 9, 10 and 11). Figure 12 shows corresponding deformations with big, no real, scale factor.

Calculated values are significantly below that making eccentricity of the crust 1.00336, what is normal. Contrary to the fluid, rigid bodies provide strong reaction to such deformation. Centrifugal forces boost the rest part of the planet to concentrate more around equator. For the same reason corresponding gravity pressure on the core can't be the same everywhere. Equatorial pressure exceeds that one on the poles performing the conditions for the contra deformation of the rotating core and adequate decrease of its eccentricity. The influence of this unfavorable situation on stability is evaluated by extended analysis of the new deformations based on the difference of mentioned pressures compare to assumed one of 3E17 N/km^2. In accordance with this it is taken for resultant equator pressure to be bigger than polar one 1.00336 times. The differences are given on Figure 13.

New finite element method results show decrease of the equatorial radius for 989.0 m and increase of the polar one for 1935.7 m. Provided "negative" eccentricity of 0.9976 doesn't lose its validity after adding of the additional deformations caused by centrifugal forces. So, extremely

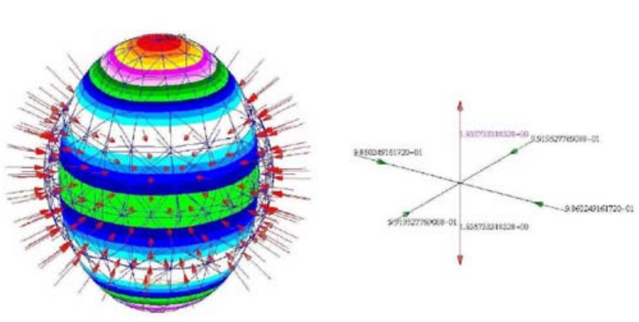

Figure 15:

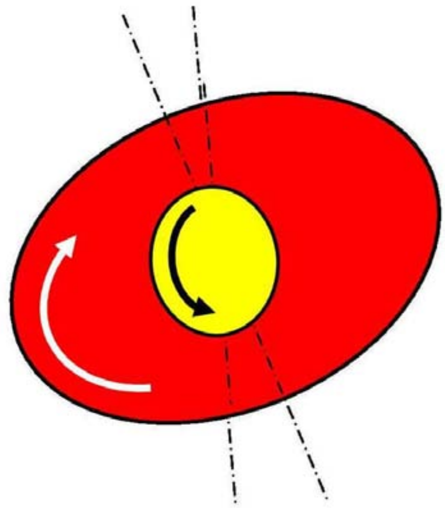

Figure 16:

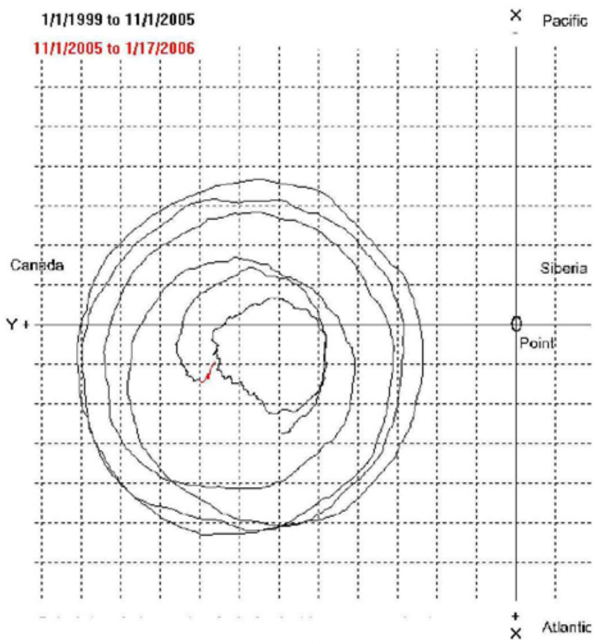

Figure 17:

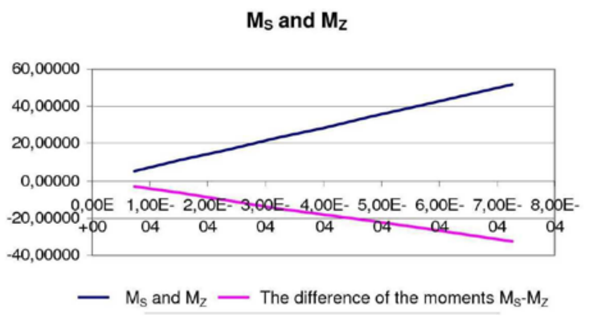

Diagram 1:

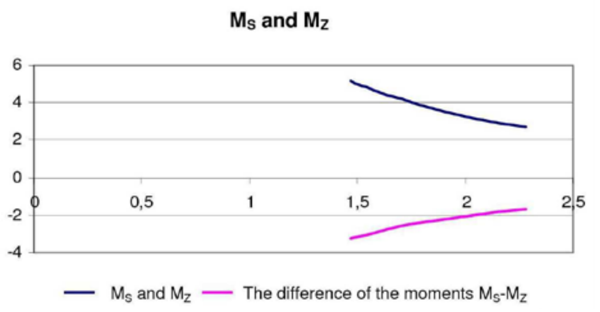

Diagram 2:

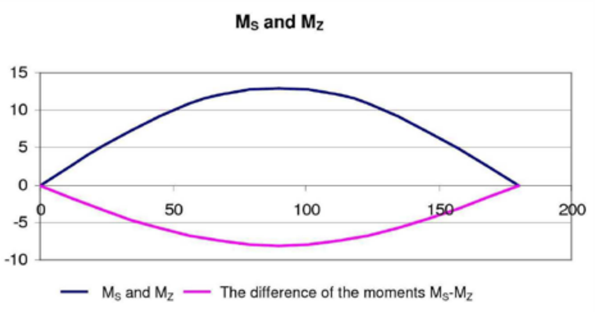

Diagram 3:

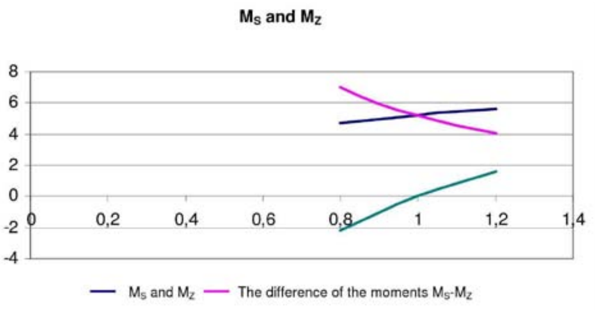

Diagram 4:

labile "contra" ellipsoid with the smaller equatorial and bigger polar radiuses obtained. That surprising result is the consequence of exceptional combination we can't meet "in small" (Figure 14 and 15).

In spite of that the result is rough it says the core is ready to rotate "down".

The answer related to the question why it doesn't happen already now could be – the friction. The rest liquid part of the planet with the opposite "sunny" moment and the shape of an ellipsoid give reasonable, but not calculated, reaction to the expected motion of the core via viscous friction, for now. Vertical sliding between inner core and the rest part of the planet could occur at one moment, causing magnetic and mechanical polar shift (Figure 16). Is it possible? It seems.

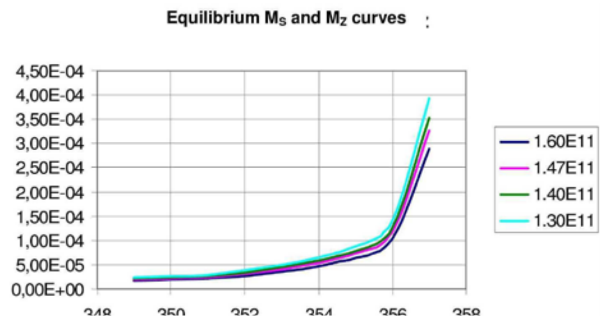

Diagram 5:

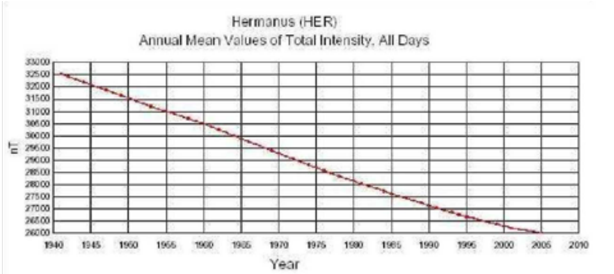

Diagram 6:

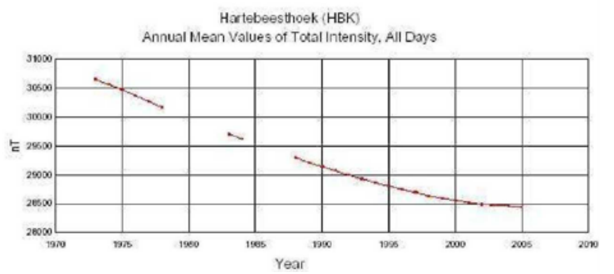

Diagram 7:

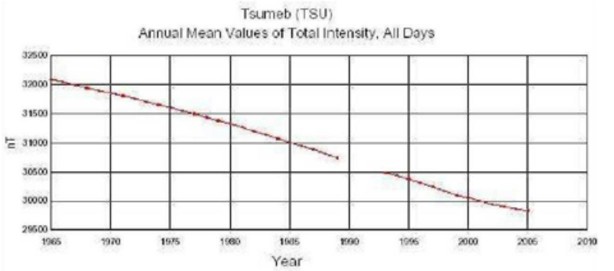

Diagram 8:

Chandler's wobble anomaly 2005/2006 is a good example for it (Figure 17). The Earth motion was in normal spiral cycle in October 2005. Suddenly, at the beginning of November, the path of own Earth rotation quickly turned side normal to the curve (red line) and stopped after corresponding slowing down about 8th of January. The point related to the North Pole left up and toward the east. Normal wobble continued after 3.5 months of the jam. Having in mind Coriolis forces pushing the core peak down and toward the west, the previous conclusion could be underlined: the sliding between core and rest part of the planet appeared for the mechanical reasons. There are some another proofs for it. One of the most popular these years could be the north magnetic pole moving toward Siberia.

So, the next scenario, in the respect of all physics laws, is very possible and real: decrease of the Earth magnetic field intensity means decrease of the angular velocity of the Earth inner core → non stable oval eccentricity of the shape of the core → advantage of the gyroscope moment → no enough capable viscous friction value to stopthe event → vertical rotation "down" of the core for almost 180° → vertical rotation "up" of the rest of the planet for unknown angle → magnetic and mechanical polar shift → new sunrise on the west after a certain period.

When? Is it possible to estimate that period? Yes, it is, of course. Very interesting results could be provided by mathematical analysis of the total intensities of the Earth magnetic field diagrams. Famous procedure related to the first derivative of the curves can give their predicted minimums. After such minimums the field should rise again (not to disappear), what is very clear having in mind the type of the diagrams. The results concerning the parts of the curves closer to the near future, made 2006 year, give (Diagrams 6, 7, 8) 2013 year for African Hermanus Magnetic Observatory, 2006 for Hartebeesthoek, 2012 for Tsumeb, 2022 for Greenland Narsarsuaq, 2023 for Qeqertarsuaq and 1999 for Qaanaaq. The average value is 2012!?

The new analysis made 2009 year gives new evidence:

$y = 2x^2 - 8067x + 8{\cdot}10^6$	Hermanus	$y' = 4x - 8067 = 0 \rightarrow 2016.75$
$y = 1.5x^2 - 6025x + 6{\cdot}10^6$	Hartebeesthoek	$y' = 3x - 6025 = 0 \rightarrow 2008.33$
$y = 4x^2 - 16074x + 2{\cdot}10^7$	Tsumeb	$y' = 8x - 16074 = 0 \rightarrow 2009.25$

AVERAGE YEAR = (2016.75+2008.33+2009.25)/3 = 2011.44

Reference

1. General knowledge of mechanics.
2. Any of the FEM programs.
3. Hermanus Magnetic Observatory Data.