EMPIRICAL KINEMATIC-GRAVITATIONAL MODEL OF GENERATION OF MAGNETIC FIELDS OF PLANETS

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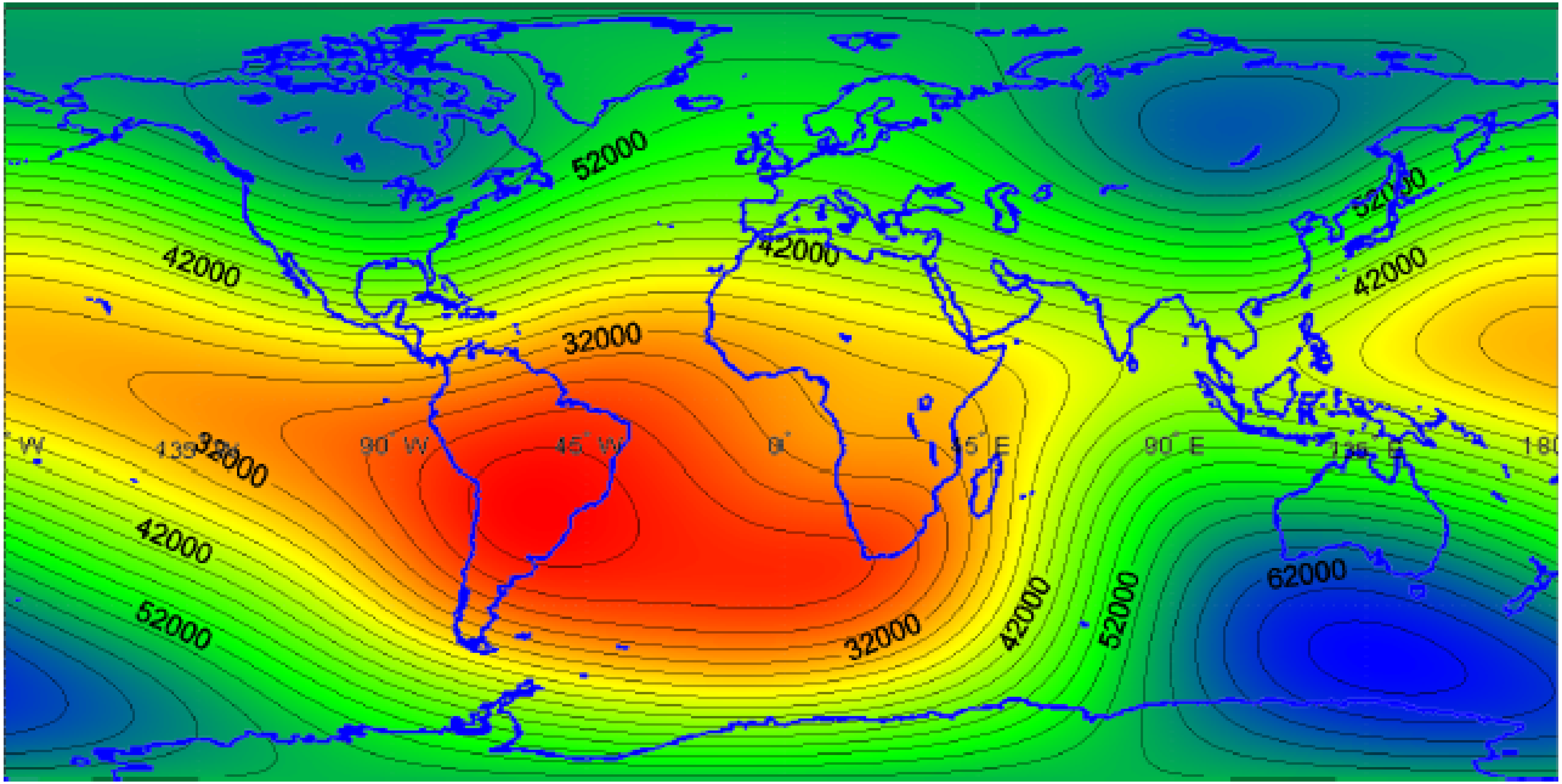
Presentation Plan

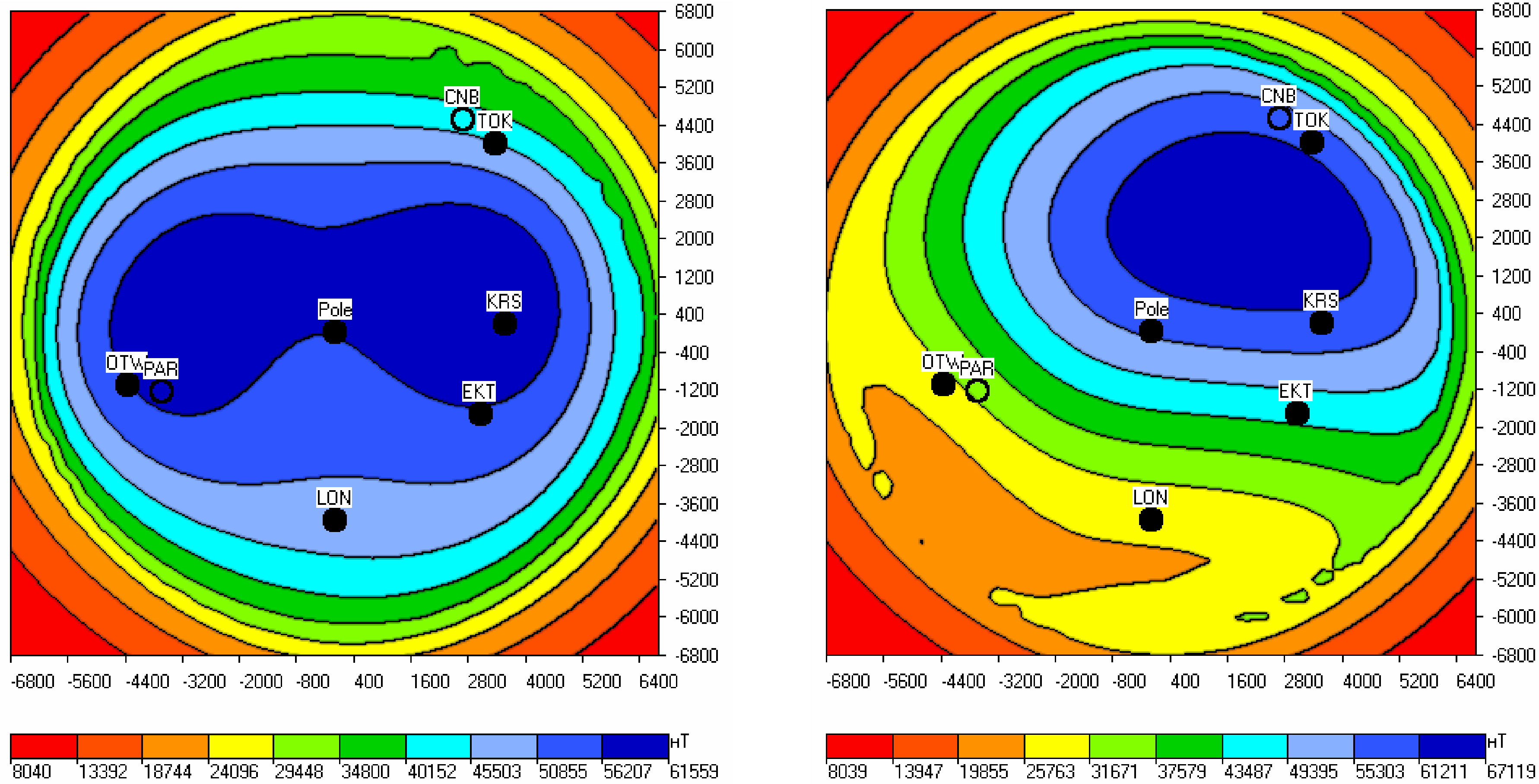
1. Earth's magnetic field
2. The results of solving the inverse problem from the magnetic field of the Earth
3. Interpretation of results
4. A brief analysis of the models of magnetic field generation
5. Estimation of horizontal gravitational forces (tidal forces)
6. Kinematical part
7. Comparison of the calculated parameters and satellite data
8. Conclusions

Earth's main magnetic field (IGRF-2005)



The main magnetic field - a view from the North Pole

The field calculated from the IGRF model (epoch 2005) on the mesh size of 35 to 35 knots at 400 km apart at an altitude of 1 km above the surface of the sphere.



The main magnetic field

The northern (left) and southern (right) hemispheres

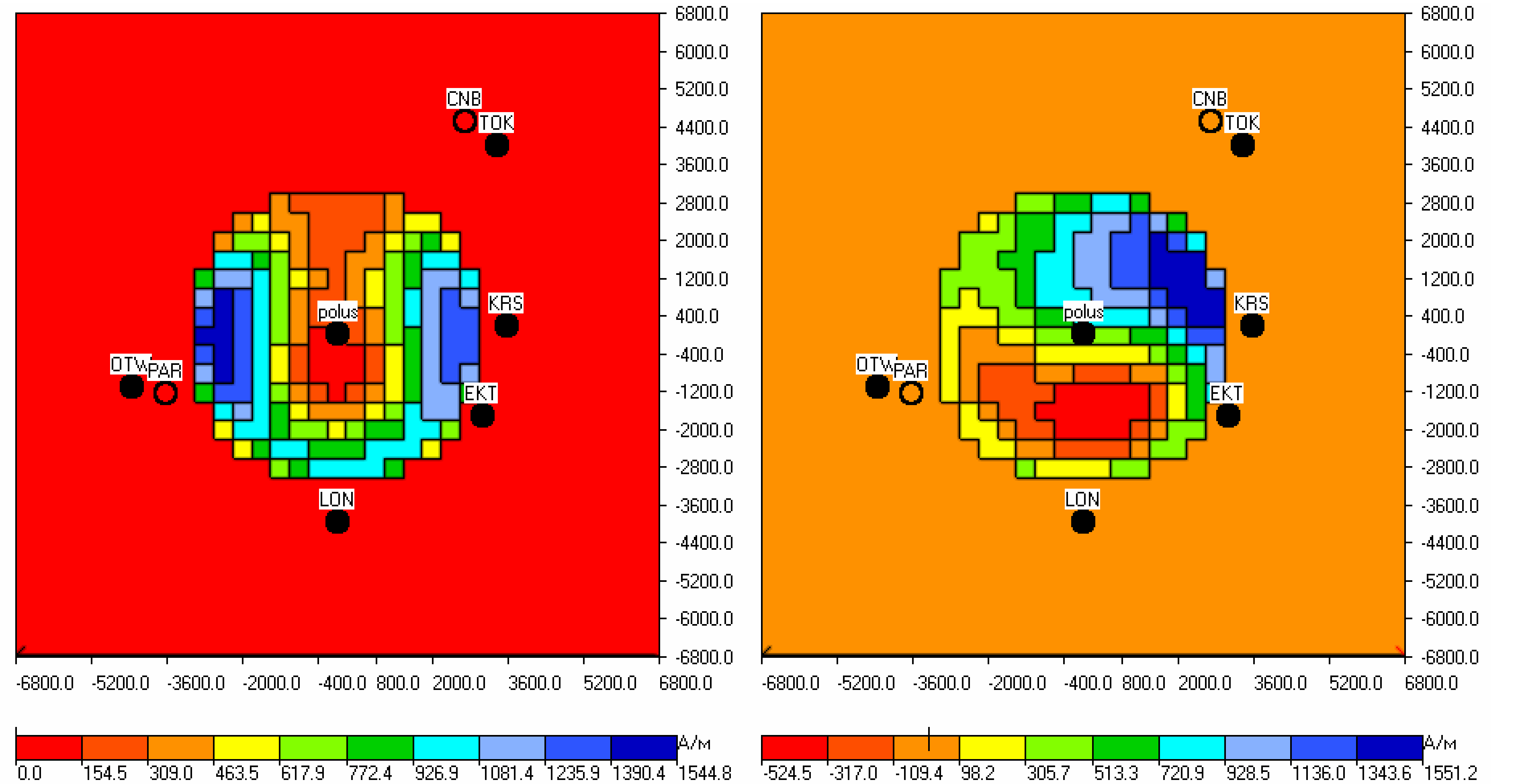
The solution of the inverse problem

On the assumption that the main source of the global magnetic field of the Earth is the core, we have solved many variants of inverse problems of magnetometry with different formulations.

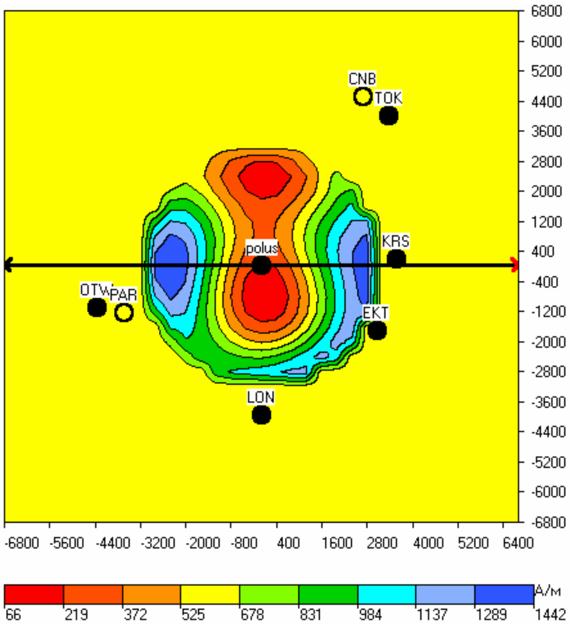
In recent work [1] [2] it was shown that the inverse problem can be robustly solved using geocentric Z-component of the main magnetic field. Various formulations yielded closely resembling models of effective magnetization of the core. The model includes three major anomalies: two in the northern and one in the southern hemispheres. In what follows we call these anomalies Canadian, Siberian and Australian, as they create on the surface global anomalies with the corresponding names.

1. Кочнев В.А., Гоз И.В. Модель источников магнитного поля ядра Земли, полученная в результате решения обратной задачи магнитометрии. // Мат. 38-й сессии Международного семинара им. Д.Г. Успенского «Вопросы теории и практики геологической интерпретации геофизических полей». Пермь, 2011.
2. Кочнев В.А. Эффективная намагниченность ядра — результат решения обратной задачи по геоцентрической Z-компоненте магнитного поля IGRF-2005. // Шестые научные чтения Ю.П. Булашевича “Глубинное строение, геодинамика, тепловое поле Земли, интерпретация геофизических полей”. Екатеринбург, 2011.

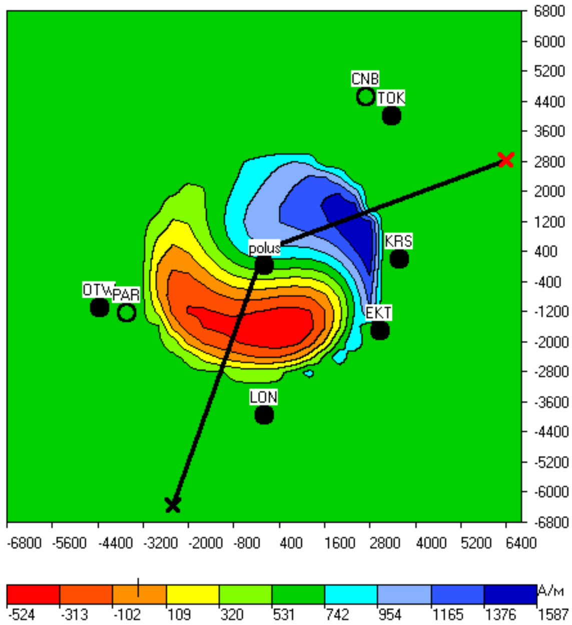
The results of solving the inverse problem, the effective magnetization



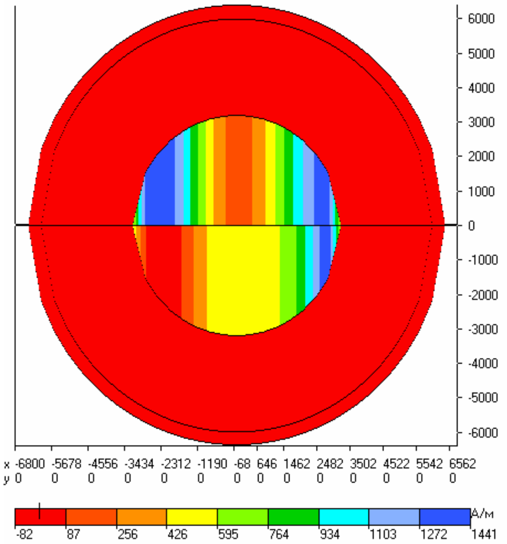
The effective magnetization of the core (northern and southern hemisphere), obtained after solving the inverse problem of magnetometry. Dimensions of the horizontal cross-sections of prisms 400 to 400 km.



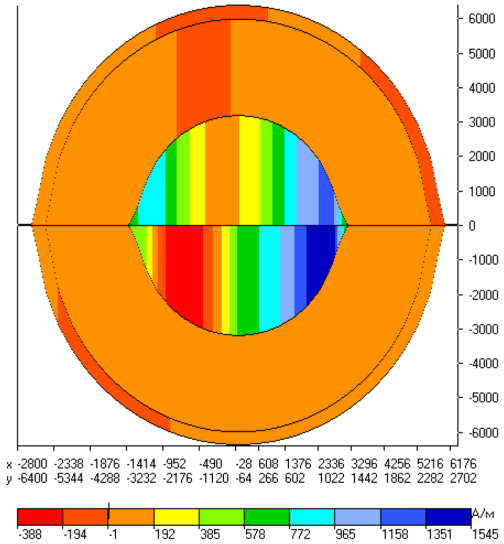
Effective magnetization of the northern hemisphere of the core



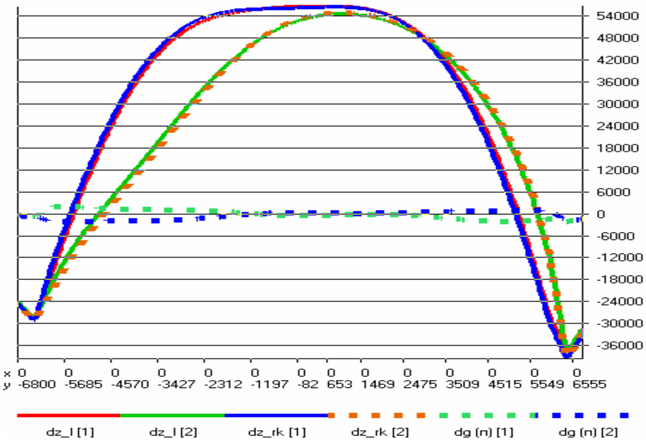
Effective magnetization of the southern hemisphere of the core



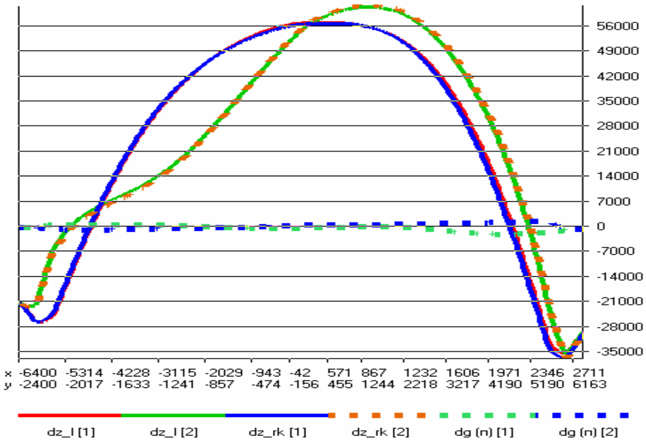
Cross-section –270-90°



Diagonal cross-section

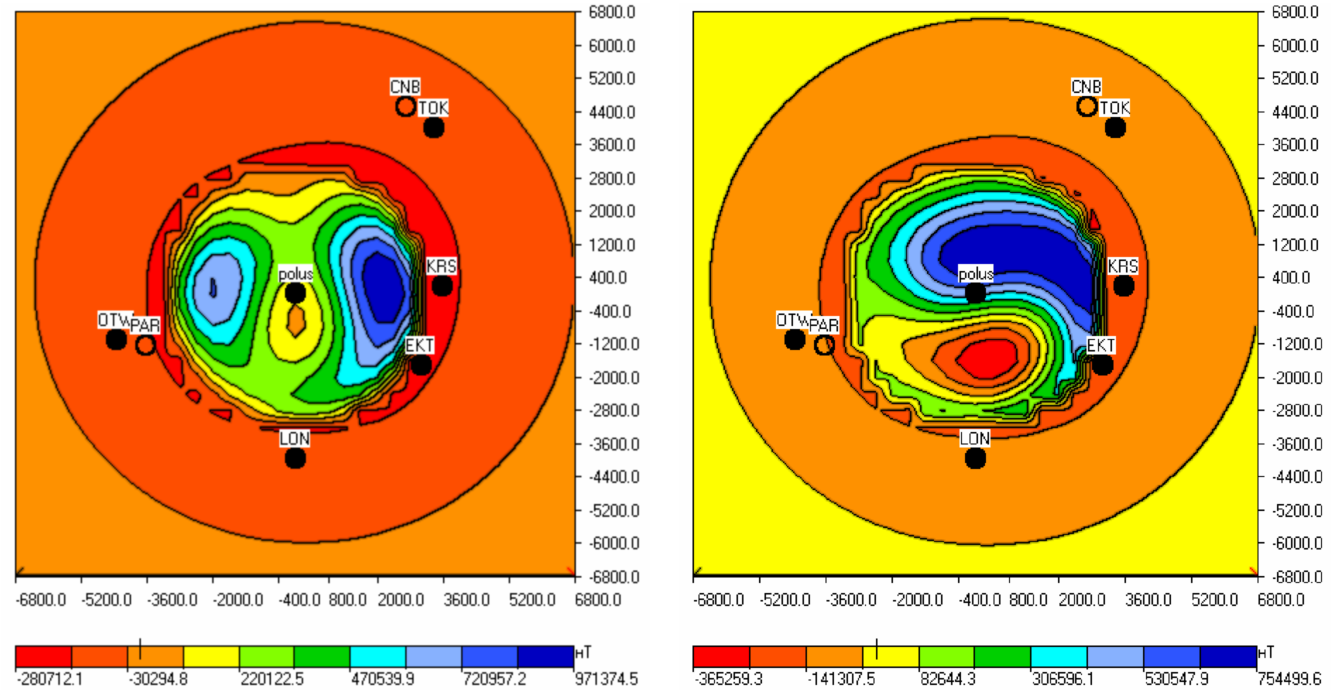


Graphs of the original field and the model field on the cross-section –270-90°



Graphs of the original field and the model field on the diagonal cross-section

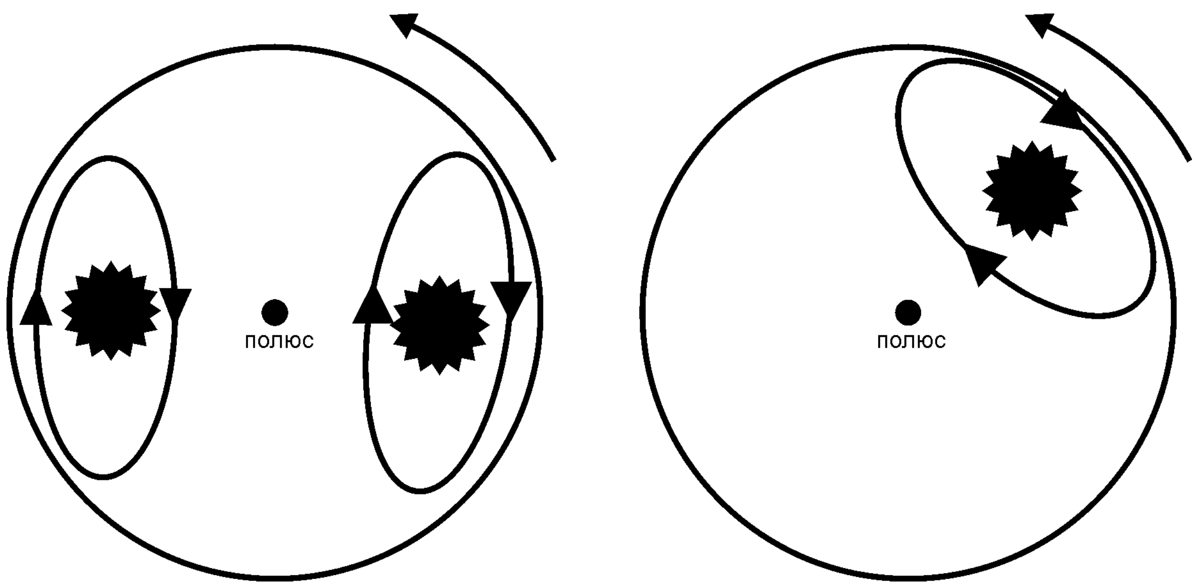
Interpretation of the results



Northern Hemisphere   Southern Hemisphere

Geocentric Z-component of the field

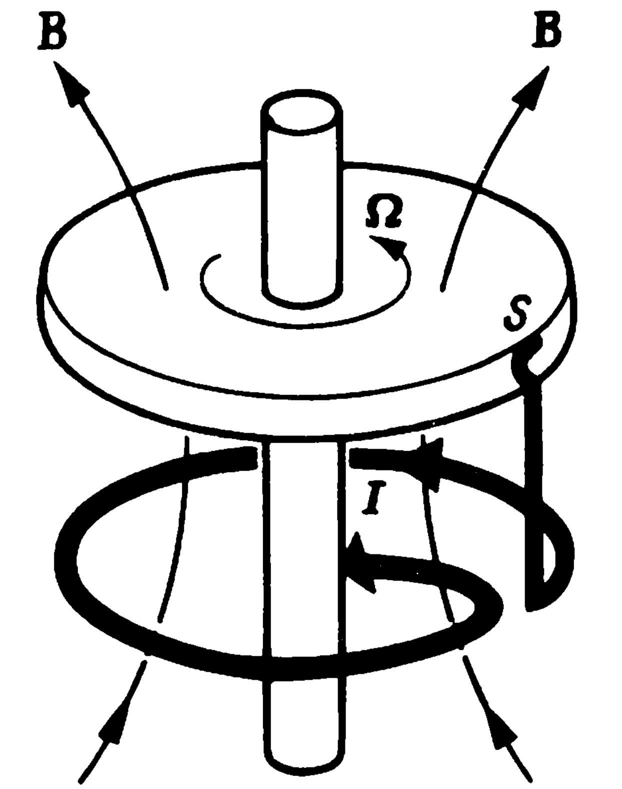
By the right-hand rule to create the main anomalies currents in the core must move in a clockwise direction, and near the equator they will move in the opposite direction to the rotation of the planet.



Analysis of models

Hundreds of mathematical models of geodynamo based on the currents in the conductive layer has been proposed. All of them are complex, such as the Bullard model [3], where eight transitions (current - magnetic field - current) required to get something close to the current model generating field in the desired direction (but not its configuration on the surface of the core or the Earth).

There is a principle in modeling: if the model is complex - its usefulness is questionable. This is why explanations of the geodynamo use simple models with a rotating disk [4].



Unipolar disk dynamo. Note that the wire through which current flows, should be twisted in the same direction as the rotating disk.

Applications of this model to the conditions of the planet was not successful [4].

Electrical current — the movement of charged liquid (plasma)

However, one can get similar model of self-sustaining dynamo, assuming that the moving liquid mass of the core is the carrier charge, i.e. it is the electrical current. Scientists estimate that the core has a temperature of about 5000°C. At such high temperatures, the chemical elements that make up the core, will inevitably become ionized — lose their outer shells electrons. The degree of ionization can be estimated by current density of electron emission occurring in the heated metals [5].

$$J \approx AT^2 \tag{1}$$

where *J* — the emission current density (A/м^2),
T — thermodynamic temperature (K),
A — a constant that depends on the metal and the conditions of the emission.

In fact, we just make the first important assumption in the model creation.

3. Яновский Б.М. Земной магнетизм. Л., 1978. 592 p.

4. Моффат Г. Возбуждение магнитного поля в проводящей среде. М.: Мир, 1980. 335 с.

5. Кухлинг Х. Справочник по физике. М.: Мир, 1982.

ESTIMATION OF HORIZONTAL GRAVITATIONAL FORCES (TIDAL FORCES)

We must take several steps to create a model.

Step 1. Let the object S be the Sun or a satellite of the planet and D will be the point inside the planet or on it or above it. Its coordinates are determined by the parameters R, r and θ. In addition, the point has unit mass. This is illustrated by Figure 3, copied from the work [6].

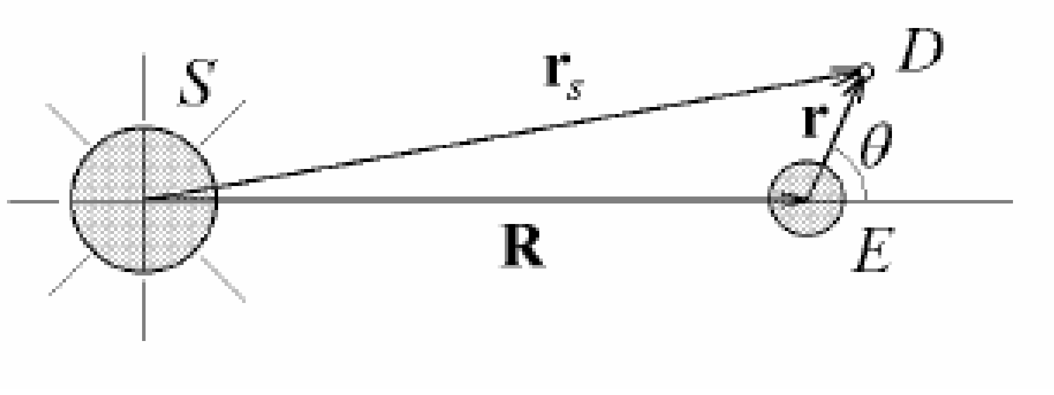


Рис. 3. Переменные r и θ, используемые для указания положения произвольной точки вблизи Земли.

6. Бутиков Е.И. Физика океанских приливов в компьютерных моделях. Санкт-Петербург: СПбГУ, 2007.

The acceleration of the gravitational force acting on an object of unit mass in the center of the planet is equal to

$$\Delta g_{sp} = G\frac{m_s}{R^2} \qquad (2)$$

Step 2. For an object of unit mass and coordinates r, θ horizontal component of gravity is calculated. According to [6] and other works, the horizontal component is equal to

$$\Delta g_{hor} = -\frac{3}{2}\Delta g_{sp}\frac{r}{R}\sin 2\theta \qquad (3)$$

Assuming $\theta = 45^\circ$, we obtain the maximum value of the horizontal component of gravity.
Note: it is interesting that the Sun's Δg_{sp} is 180 times greater than that of the Moon, but Moon's Δg_{hor} is 2.5 times greater than the Sun's. This is why the Moon has the greatest influence on the amplitude of tidal currents.

KINEMATICAL PART

Step 3. It is known that the intensity of the magnetic field generated in the core, depends on the period of rotation of the planet T_{pl}. We introduce the period relative to the satellite creating Δg_{hor}

$$T_{rpl} = T_{pl}\left(\frac{T_{sp}}{T_{sp} - T_{pl}}\right) \qquad (4)$$

Note: it is easy to see that with the equality of the periods of the planet T_{pl} and satellite T_{sp} value of $T_{rpl} \to \infty$, meaning that the satellite is stationary and does not create horizontal forces on the surface of the planet.

Step 4. Calculate the total estimate Δg_{hor} for the Earth. It is created by the Moon and Sun.

$$\Delta g_{hor}(e) = \Delta g_{hor}^{Lun}(e) + \Delta g_{hor}^{Sol}(e) = \sum_{i=1}^{2} \Delta g_{hor}(e)$$

Step 5. Knowing all of the above parameters, we can calculate the total horizontal force for each of the planets in the solar system. Taking the Earth as a standard, we calculate the parameter K_N

$$K_N = \frac{\sum \Delta g_{hor}(pl) \frac{T_E}{T_{RPL}}}{\sum \Delta g_{hor}(e)} \left(\frac{r_{PL}}{r_E} \right)^N \qquad (5)$$

K_0 gives the estimate of B_{pl}/B_E, K_3 — the estimate of M_{pl}/M_E. Below is a detailed table of calculations and short table summarizing the results.

The parameters of the planets and satellites, the relative magnetic moments M_{PL}/M_E and the relative magnetic field strengths on the equator B_{PL}/B_E ant the parameters K.

Planet Rel. radius r_{pl}/r_E	Source of gravitational field	Mass of the source, kg	Orbital radius of the source, m	Rotational periods of the planet Tpl, satellite Ts, and rel. period Trpl	$\sum \Delta g_{hor}(pl)\frac{T_E}{T_{rl}}$	M_{PL}/M_E B_{PL}/B_E	K_3 K_0
1	2	3	4	5	6	7	8
Mercury 0.38	Sun	1.99E+30	5.80E+10	58 87.9 **170.5**	-1.46E-08	<0.006 **0.005-0.01**	0.0007 0.012
Venus 0.95	Sun	1.99E+30	1.08E+11	-244 224.7 **-117**	8.2E-09	<0,00001 **<9*10^{-5}**	–0.006 –0.007
Earth 1	Sun Moon	1.99E+30 7.40E+22	1.50E+11 3.84E+08	1 365 **1** 1 28 **1.04**	-3.76E-07 -8.33E-07 **-1.21E-06**	1 1	1 1
Mars 0.53	Sun Phobos	1.99E+30 1.07E+16	2.28E+11 9.40E+06	1 687 **1** 1 0.32 **-0.47**	-5.70E-08 9.65E-09 **-4.73E-08**	<0,0003 **0.0013-0.0019**	0.006 0.039
Jupiter 11.22 with other satellites	Sun Io	1.99E+30 8.93E+22	7.80E+11 4.22E+08	0.4 4332 0.4 0.4 1.8 **0.51**	-7.36E-08 -1.68E-05 -1.69E-05	20000 **14**	18495 13.94 23137 17.43
Saturn 9.47 with other satellites	Titan	1.30E+23	1.20E+09	0.4 15.9 **0.41**	-1.15E-06	600 **0.7**	792 0.95 1409 1.69
Uranus 4.01 with other Satellites	Ariel	1.35E+21	1.91E+08	0.7 2.52 **0.97**	-5.2 E-07 -9.78 E-07	 50 **0.7**	25.9 0.43 49 0.81
Neptune 3.89	Triton	2.14E+22	3.54E+08	0.8 -5.8 **0.7**	-1.74 E-06	25 **0.45**	80.7 1.44

Table of the relative magnetic moments and the field strengths from satellite observations [8], and kinematic- gravitational parameters of the planets

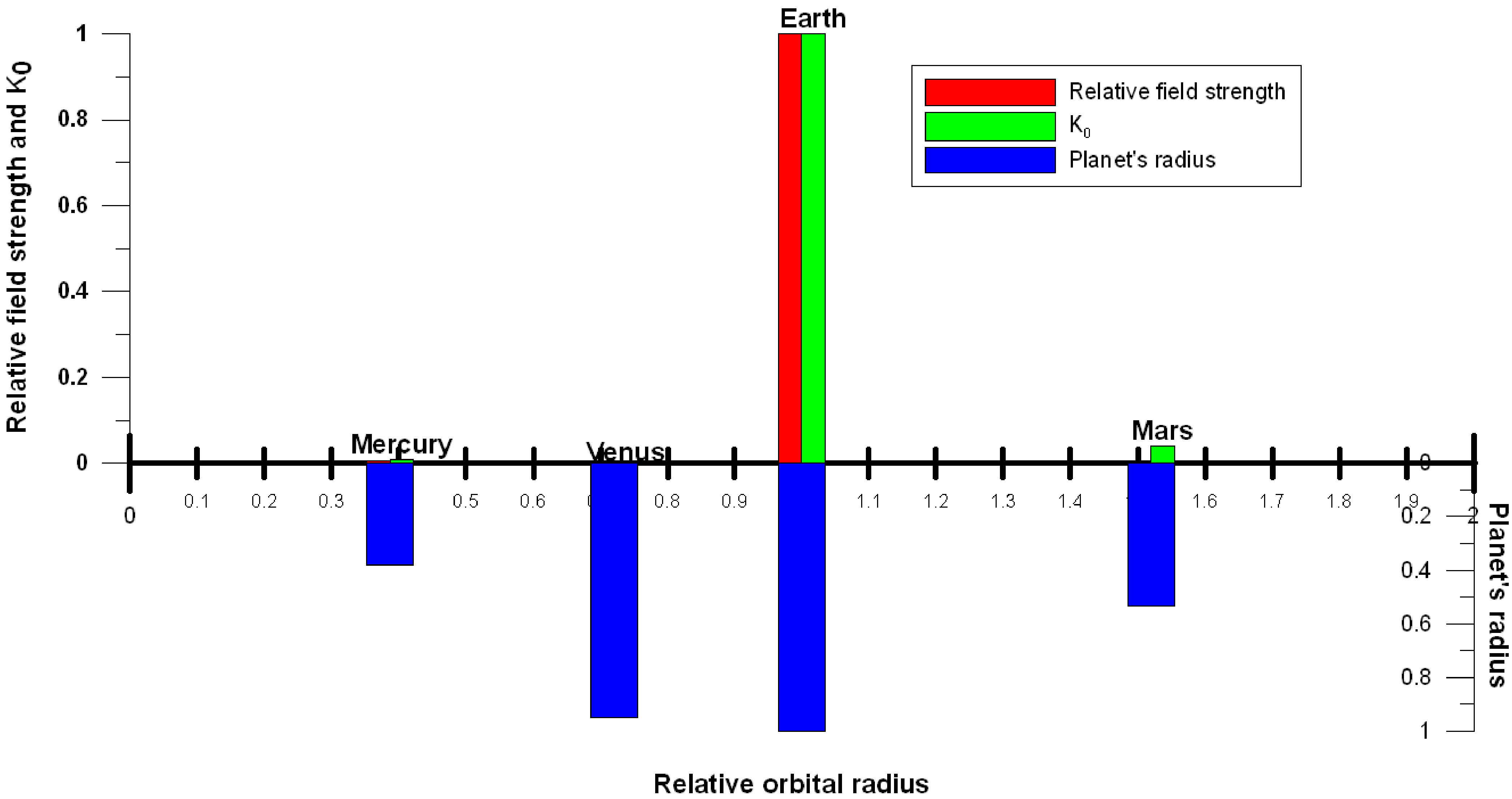
Parameter	Mercury r_{pl} =0.37	Venus r_{pl} =0.96	Earth r_{pl} =1	Mars r_{pl} =0.53	Jupiter r_{pl} =11.2	Saturn r_{pl} =9.4	Uranus r_{pl} =3.8	Neptune r_{pl} =3.6
M_{PL}/M_E	<0.006	<0.00001	1	<0.0003	20000	600	50	25
K_3	0.0007	–0.006	1	0.006	23137	1409	49	80.7
B_{PL}/B_E	0.007	<0.00009	1	0.0016	14	0.7	0.7	0.45
K_0	0.012	–0.007	1	0.039	17.43	1.69	0.81	1.44

Under the names of the planets are the relative radii, moments and induction at the equator, taken from [7].

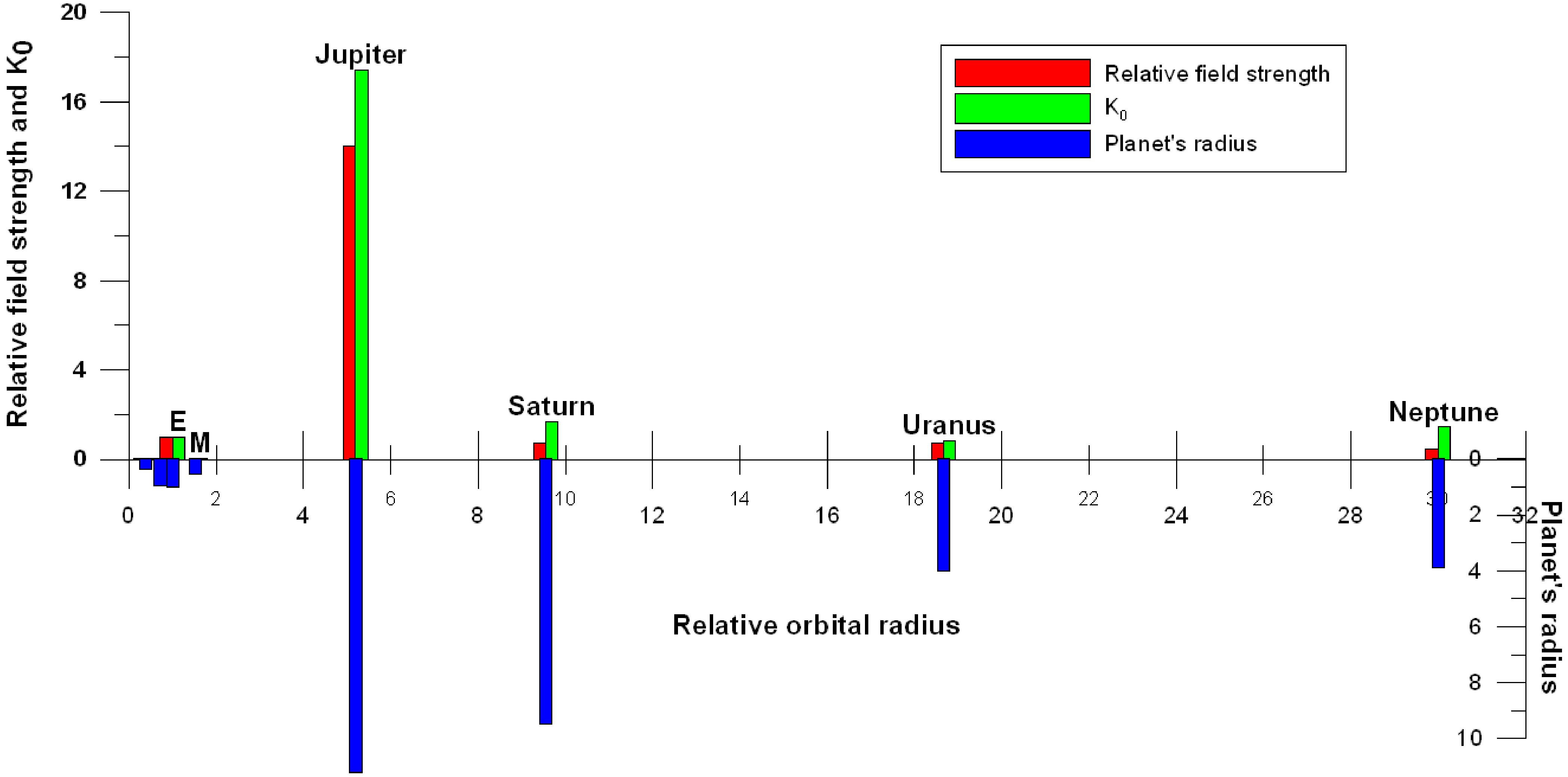
7. Гордин В.М. Очерки по истории геомагнитных измерений. М.: ИФЗ СО РАН, 2004. 161 .

No time to comment. Let me just say one thing: the correlation coefficient between the calculated parameters and taken from the work of Gordin [7] is equal to 0.997.

I have to pause the presentation due to lack of time and provide the conclusion.



Relative field strength on equators, parameter K_0 and planet's radius.



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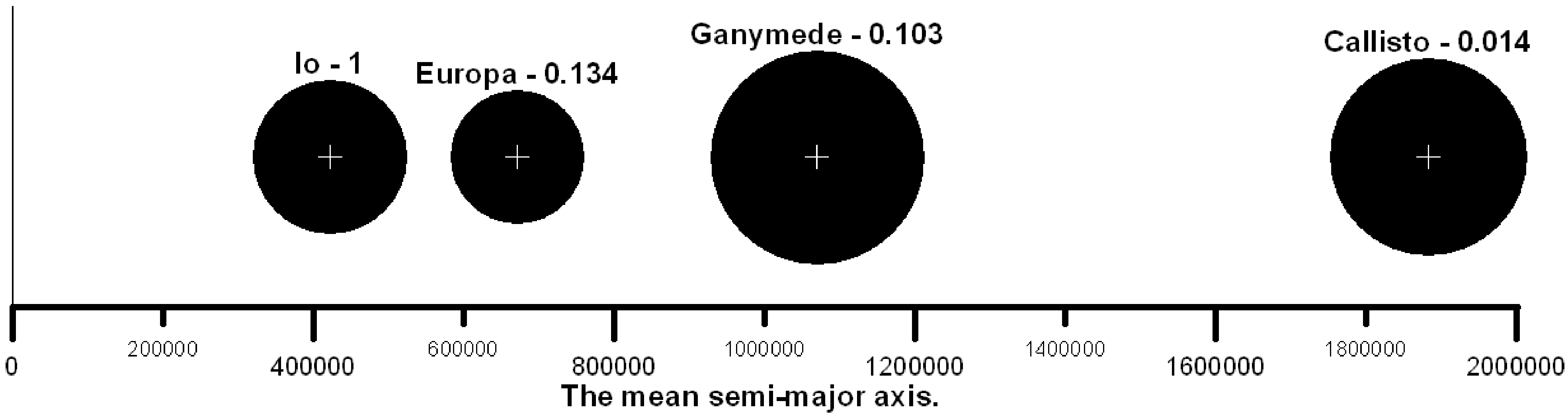
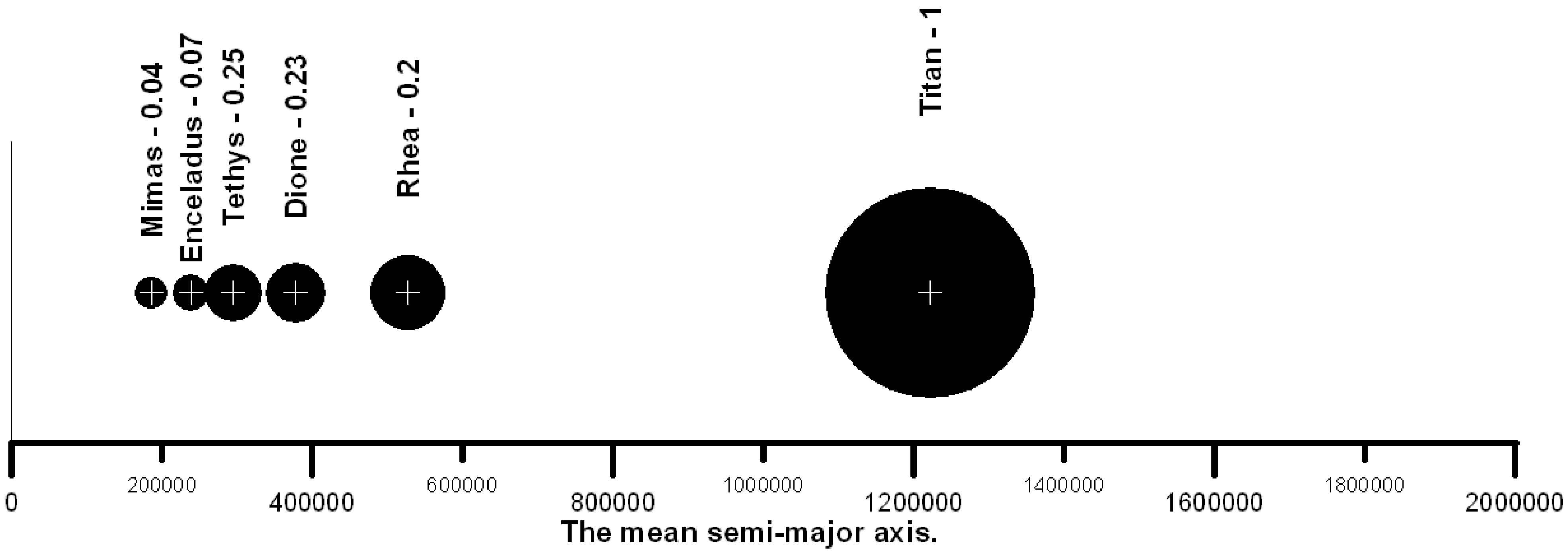
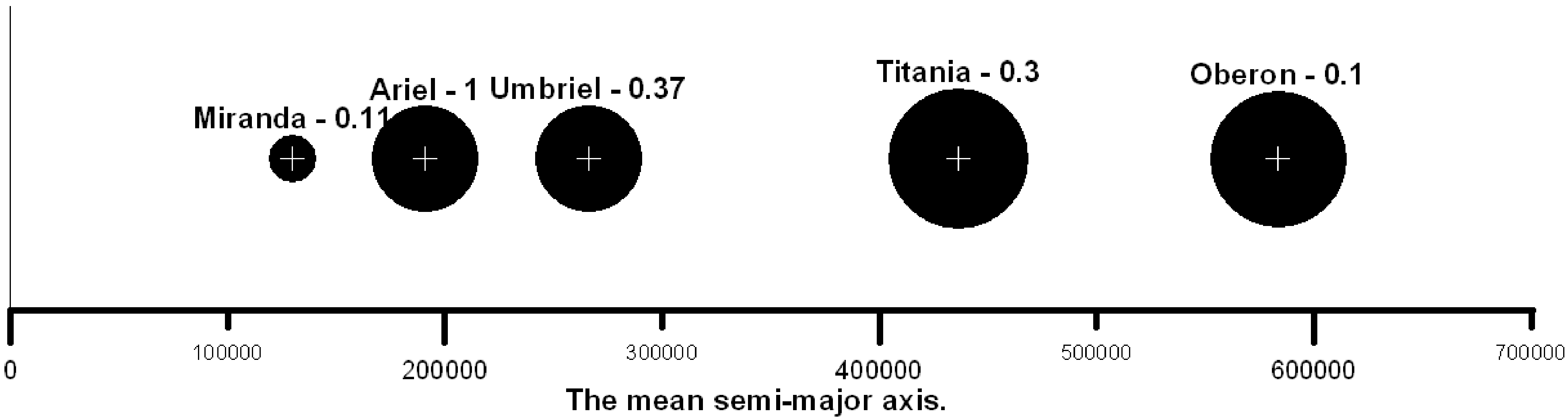


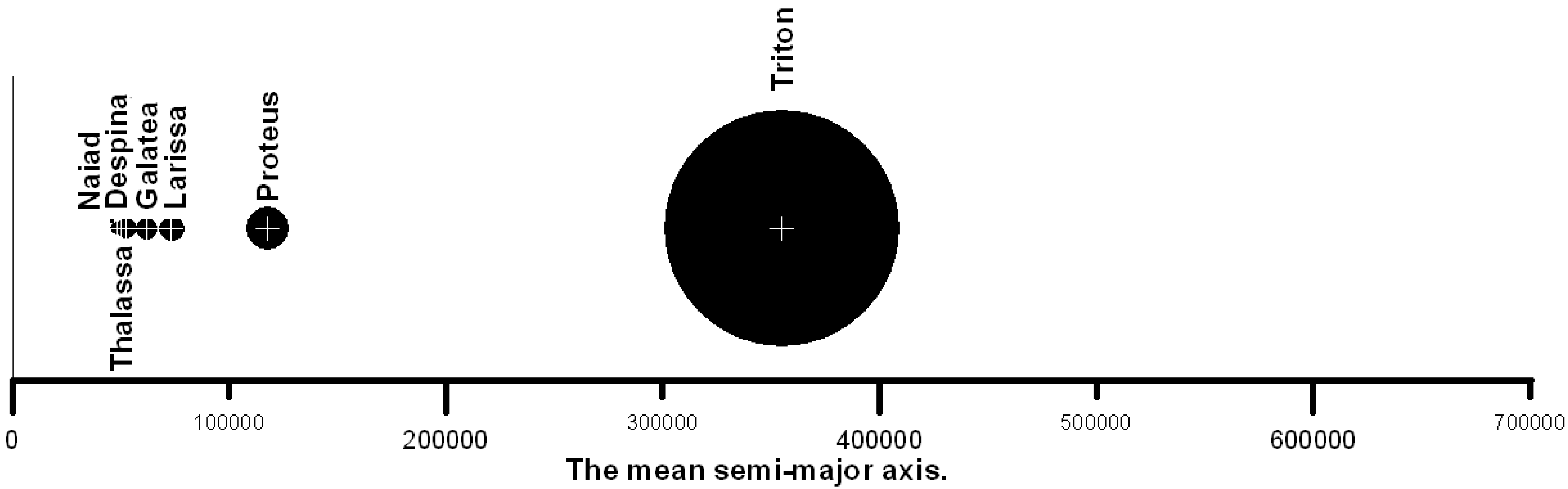
Largest moons of Jupiter



Largest moons of Saturn



Largest moons of Uranus



Largest moons of Neptune

Conclusions

Thus, the kinematic-gravity model for the emergence of a magnetic field requires the following conditions.

1. Liquid core, whose atoms are ionized under the action of heat. The higher the temperature, the greater the ionization and, consequently, a charge of the liquid.

2. The rotation of the planet on its axis. In accordance with the empirical formula parameters of the magnetic field are proportional to the angular velocity of rotation. In the presence of a liquid and heated core, but with slow rotation (as Venus), magnetic field will be weak.

3. The presence of one or more external objects (the sun or satellites), creating a tidal forces that cause motion of the liquid on the surface of the planet (trade-wind flow), and in the liquid core. The tidal force is proportional to the mass of the object, the radius of the planet and inversely proportional to the cube of the distance of the object from the planet.

Large satellites of the planets cannot generate its own field due to their planet, even if they have a liquid core, because, according to the available information, the periods of revolution around the axis and the planet are the same. Consider the Moon as the planet and Earth as a satellite. The Earth is a stationary satellite. According to the formula (4) $T_{rpl} = \infty$, and K0=K3=0.

Minor field of the Moon and some satellites of Jupiter can be created by tidal forces of the Sun. But this is a special topic for study.

Thank you for your attention!

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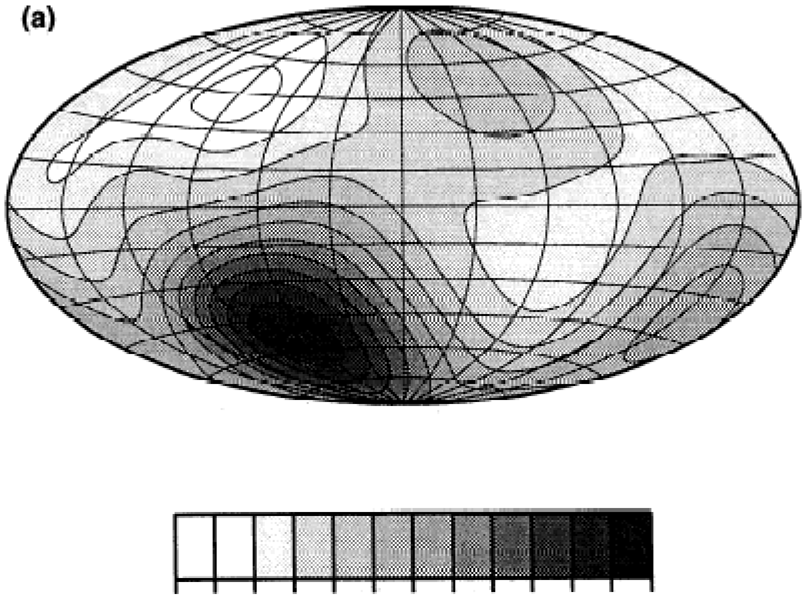

Figure 11. A comparison of (a) minimum norm and (b) truncated SVD solutions for the surface magnetic field intensity of Uranus. Field strength in Gauss (10^{-4} T).

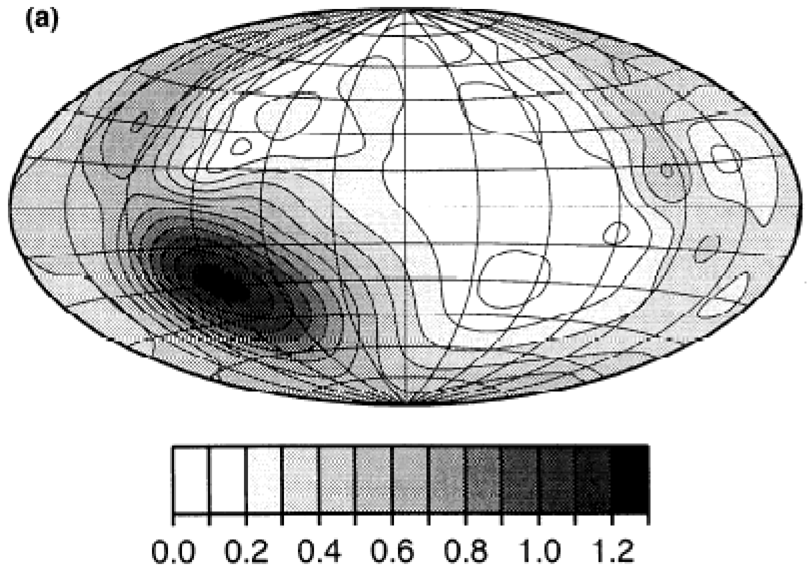

Figure 13. A comparison of (a) minimum norm and (b) truncated SVD solutions for the surface magnetic field intensity of Neptune. Field strength in Gauss (10^{-4} T).

Holme R., Bloxham J. The magnetic fields of Uranus and Neptune: method and models // Journal of Geophysical Research. 1996. Vol. 101, № E1. P. 2177–2200

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