УЧЁТ ВЛИЯНИЯ МАГНИТОСФЕРЫ и ИОНОСФЕРЫ НА ВЫЧИСЛЕНИЕ СКОРОСТИ УМЕНЬШЕНИЯ ГЛАВНОГО ГЕОМАГНИТНОГО ДИПОЛЯ В ПОСЛЕДНЕМ ДЕСЯТИЛЕТИИ

Анатолий Левитин, Сергей Филиппов, Татьяна Зверева

ИНСТИТУТ ЗЕМНОГО МАГНЕТИЗМА, ИОНОСФЕРЫ и РАСПРОСТРАНЕНИЯ РАДИОВОЛ РАН (ИЗМИРАН)
им. Н.В.Пушкова

Троицк, Московской обл., Россия
http://www.izmiran.ru

Russian Academy of Science

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THE ACCOUNT OF INFLUENCE OF MAGNETOSPHERE AND IONOSPHERE ON CALCULATION OF GEOMAGNETIC DIPOLE INTENSITY DECREASE DURING LAST DECADE

Anatoly Levitin, Sergey Filippov, Tatjana Zvereva

PUSHKOV INSTITUTE OF TERRESTRIAL MAGNETISM, IONOSPHERE AND RADIO WAVE PROPAGATION (IZMIRAN)

Troitsk, Moscow Region, Russia *http://www.izmiran.ru*

IZMIRAN

Russian Academy of Science

Outline

- Introduction – What is the problem ?
- Geomagnetic field modeling
- Two parameters of solar activity
- Our estimation of the geomagnetic dipole intensity decrease
- Conclusions
- Main result – …

Introduction

Geomagnetic field $\boldsymbol{H}(z,\varphi,\lambda,t)$ comes from various sources located inside (core and lithosphere) and outside (ionosphere and magnetosphere) of the Earth. So it can be presented as a sum of two parts - internal ($\boldsymbol{H}_{\mathbf{int}}$) and external ($\boldsymbol{H}_{\mathbf{ext}}$):

$$\boldsymbol{H} = \boldsymbol{H}_{\mathbf{int}} + \boldsymbol{H}_{\mathbf{ext}}$$

Both parts subject to temporarily changes. The internal part is usually referred as main geomagnetic field (MGF) and its changes are named as annual or secular variations.

Presently there are a lot of worries in press that the MGF promptly decreases and it faces extinction in 1200-1500 years, i.e. in these years there will come "doomsday".

As our reaction to this ‘dramatic’ prediction, we assessed the speed of the MGF decrease.

The key moment of our examination is that we properly account for the geomagnetic activity caused by magnetosphere-ionosphere current systems.

Numerical models of MGF field

One of the approaches to find the decrease of the MGF is to analyze numerical models of the field.

Traditionally, the MGF models are constructed on the basis of spherical harmonic analysis (SHA) .

Internal geomagnetic field on the surface of the Earth can be represented as the gradient of a scalar magnetic potential

$$\boldsymbol{H} = -grad\ \boldsymbol{V},$$

which is expanded as well-known formula:

$$V(r,\vartheta,\lambda,t) = R\sum_{n=1}^{n_{\mathrm{MAX}}}\left(\frac{R}{r}\right)^{n+1}\sum_{m=0}^{n}\left[g_n^m(t)\cos m\lambda + h_n^m(t)\sin m\lambda\right]P_n^m(\cos\vartheta)$$

where *r, θ, λ* are the geocentric coordinates (*r* is the distance from the center of the Earth, *θ* is the colatitude, and *λ* is the longitude), *R* is a mean radius (6371.2 km) of the Earth;

g_m^n and h_m^n are the expansion coefficients and P_m^n are the Schmidt semi-normalized associated Legendre functions of degree *n* and order *m*.

The essential part of energy of the MGF is represented by its dipole part - the first three coefficients - g_1^0, g_1^1 , h_1^1 .

Moreover, the coefficient g_1^0 surpasses each of coefficients h_1^1, g_1^1 in 15 times.

Therefore, comparing the values of these coefficients g_1^0 g_1^1, h_1^1 for different epochs, we actually, can define the speed of the MGF decrease.

International Geomagnetic Reference Field (IGRF) is an example of such model. IGRF model presents the MGF and its secular variations.

We analyzed coefficient g_1^0 of the IGRF model for epochs of 1960 -2005 (see next Table):

Coefficient g_1^0 of IGRF model and its speed for epochs 1960-2005

IGRF	g_1^0 (nT)	$\dot{g}_1^0$ (nT/yr)
1960	- 30421	-
1965	- 30334	17
1970	- 30220	23
1975	- 30100	22
1980	- 29992	21
1985	- 29873	24
1990	- 29775	20
1995	- 29692	17
2000	- 29619	15
2005	- 29556	13

It is obvious, that the speed in 15-20 nT/year in 1500 will reduce this coefficient, i.e. dipole magnetic field, practically down to zero.

The models till 1980 were made basically on ground data. However, the satellite data were already used in the last models, but anyway the jumps in data of the Table are not visible.

Basic idea of our research:

(a) IGRF coefficients are influenced by a source of external origin that are not accounted for by the IGRF models;

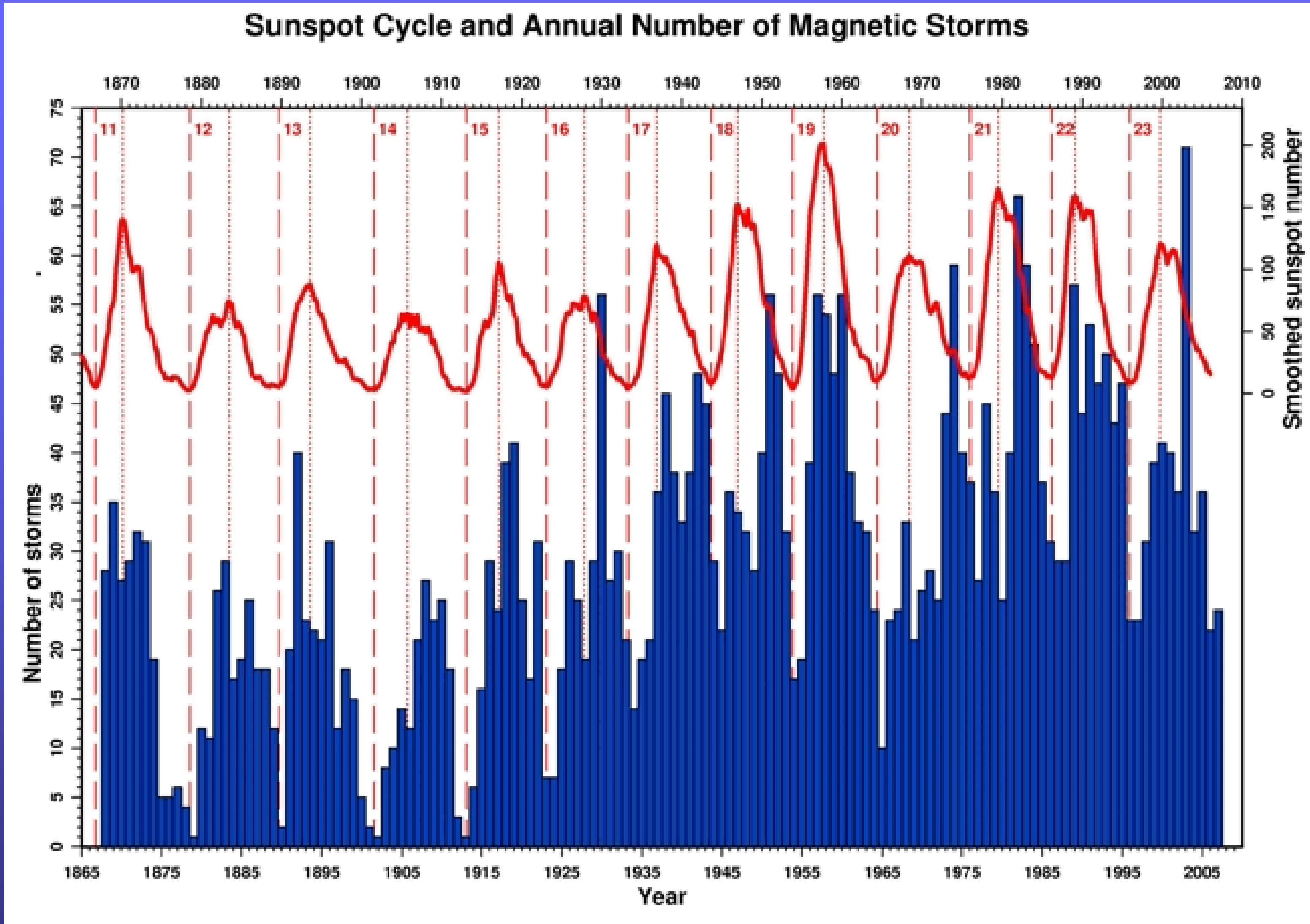
(b) proper account for this source impact should correct the MGF velocity.

Let us now consider the following two parameters that reflect the solar activity.

Parameters of solar activity

It is known, that the external magnetic field is generated by currents in the Earth's ionosphere and magnetosphere by direct influence of solar activity.

The next slide presents the annual number of magnetic storms (blue histogram) and the smoothed sunspot number (red curve).



http://www.geomag.bgs.ac.uk/earthmag.html

The red curve is the smoothed sunspot number.

The figure demonstrates:

- the correlation of magnetic activity (external magnetic field) with the solar activity and

- the apparent increase in magnetic activity with time.

We tried to quantitatively find this correlation with the use of the following two parameters:

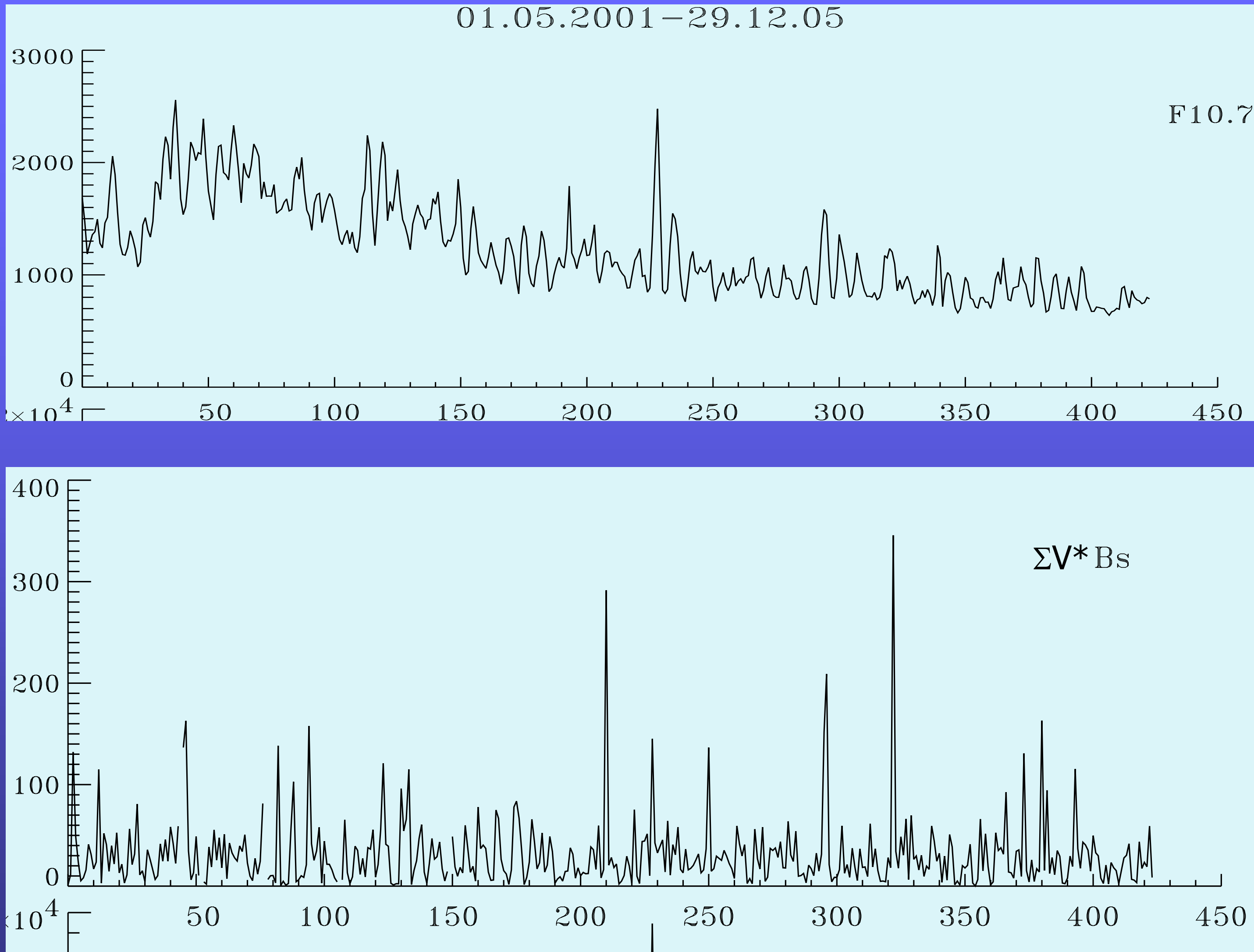
(1) solar activity index - F10.7 - a stream of a Sun's radio emission on a wave of 10.7 sm. In our case, its daily average amplitude. It reflects the influence of the wave radiation of the Sun on the Earth's ionosphere.

(2) the sum of products *V*Bs* inside of day.

Here *V* is the hourly average speed of the solar wind, and *Bs* = 0 at *Bz*> 0 and *Bs* = -*Bz*, at *Bz* <0, where *Bz* is the vertical component of the interplanetary magnetic field (IMF). This parameter reflects a level of the solar wind influence on electromagnetic condition of magnetosphere.

Both parameters together characterize the variability of the ionosphere ring current systems.

The next slide presents the time series of both parameters for the period of 4 years (May, 2001 to December, 2005). The data sampling rate is 4 days.



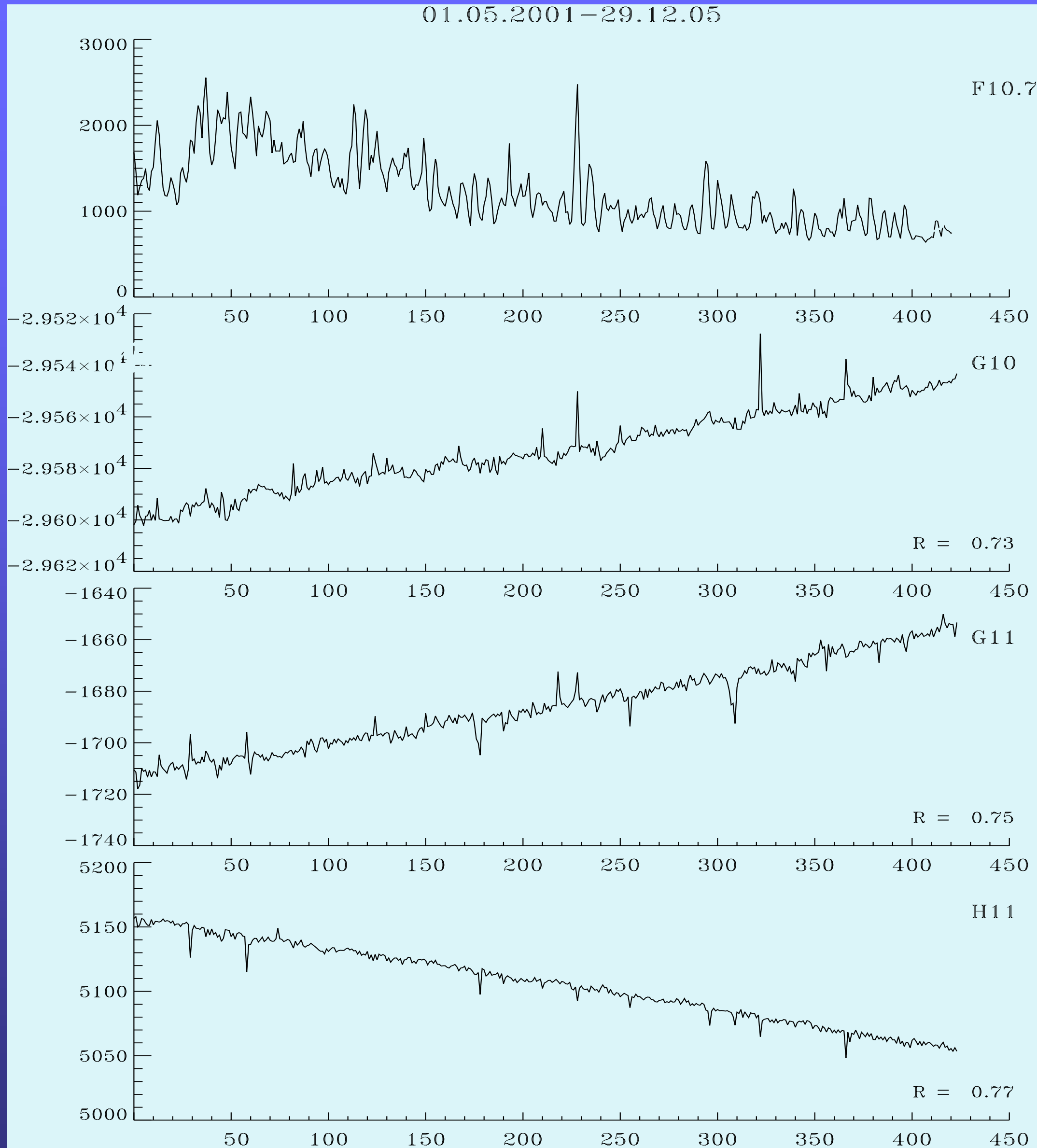
Time series of solar activity index F10.7 and ΣV*Bs

Main geomagnetic field decrease

To estimate the decrease of the MGF the CHAMP satellite data for the period of May 2001 - December 2005 were used.

We took the vector satellite data with one-second sampling rate. They were used to find daily SHA models (with up to $n=m=10$) for each 4th day. The whole number of the SHA models is 424.

The next slide shows the first three coefficients, obtained for SHA models (lower panels). The upper panel presents index F10.7.



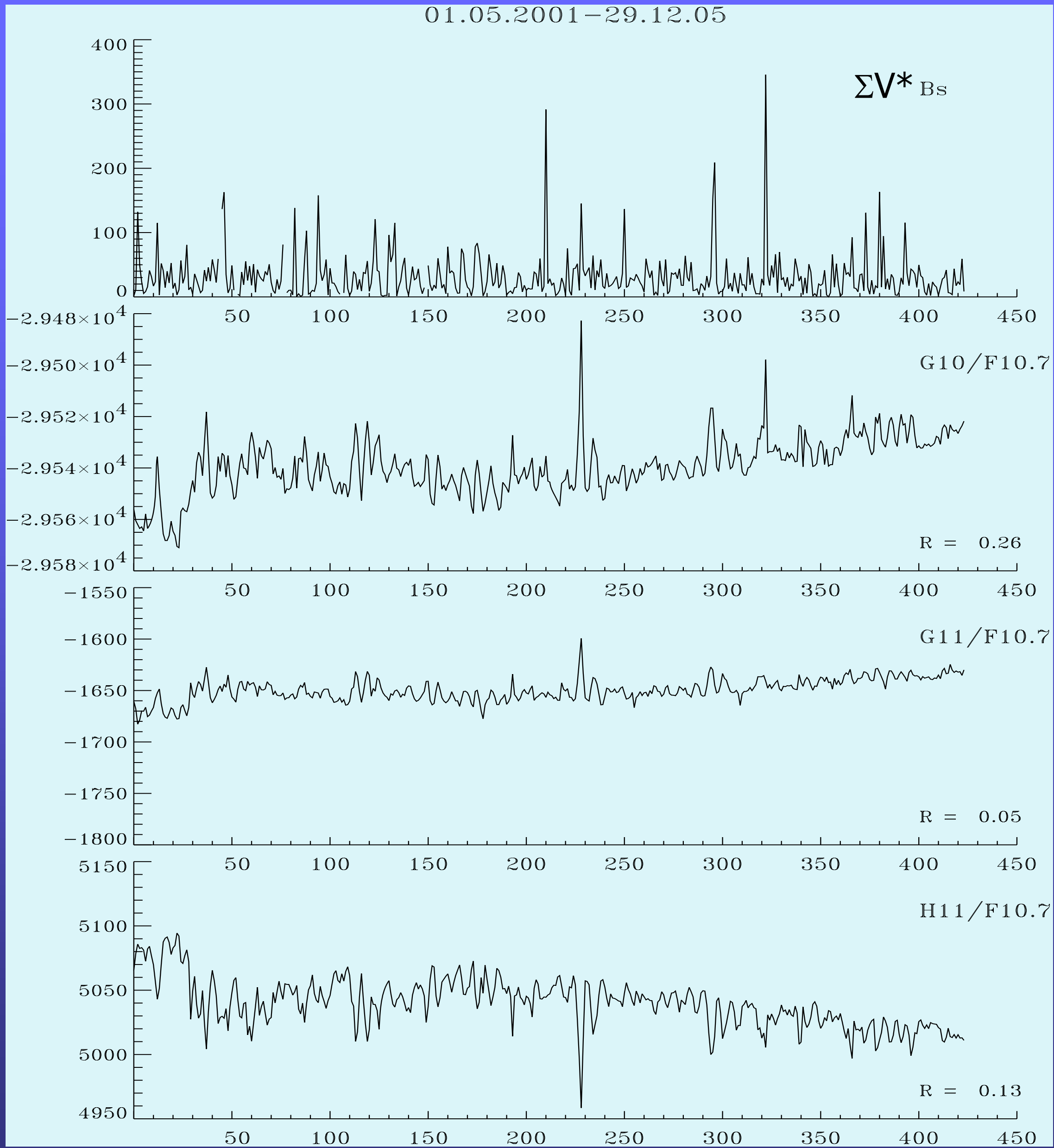
Time series of solar activity index F10.7 and coefficients g_1^0, g_1^1, h_1^1.

The coefficients g(t), h(t), indexes F10.7 and ΣV*Bs were exposed to the linear correlation analysis to find the correlation factor *R*.

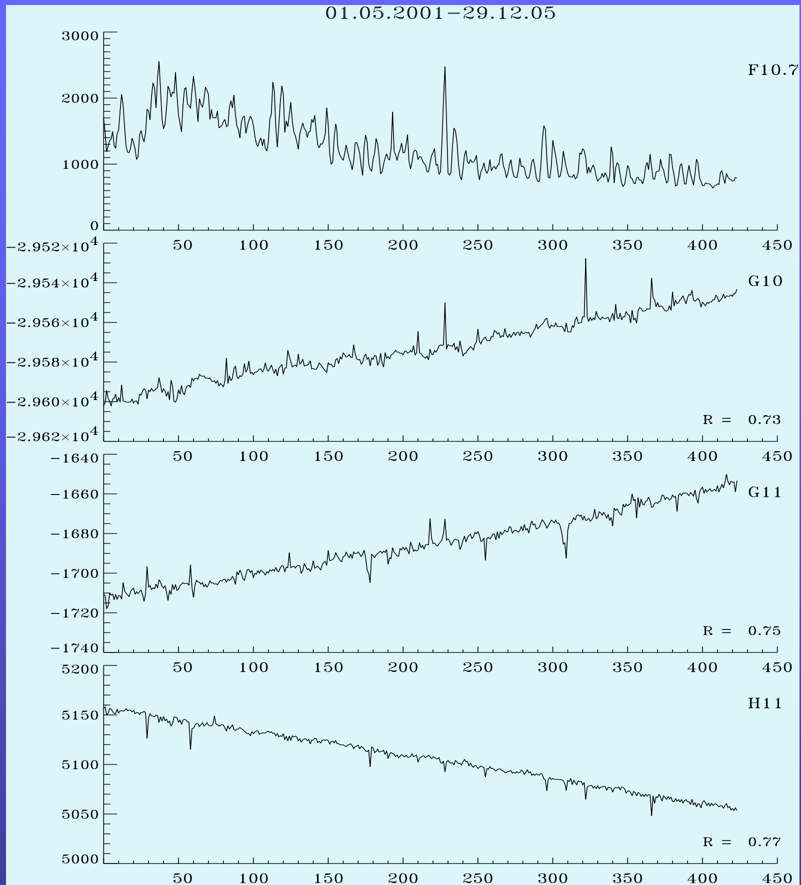
We found that the correlation factor between coefficients g_1^0, g_1^1 , h_1^1 and index F10.7 is such as R> 0.7.

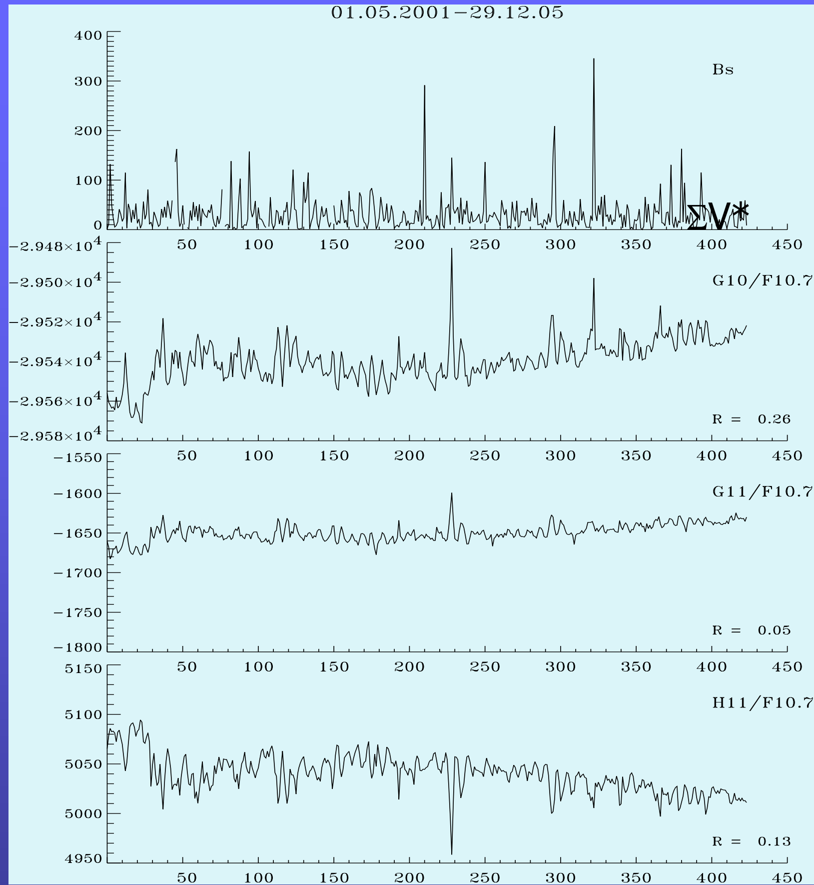
We have further cleared coefficients g (t) and h (t) of F10.7's connection.

The next slide shows these cleared coefficients - G10/F10.7, G11/F10.7 and H11/F10.7.



Time series of solar activity index ΣV*Bs and cleared coefficients g_1^0, g_1^1, h_1^1.

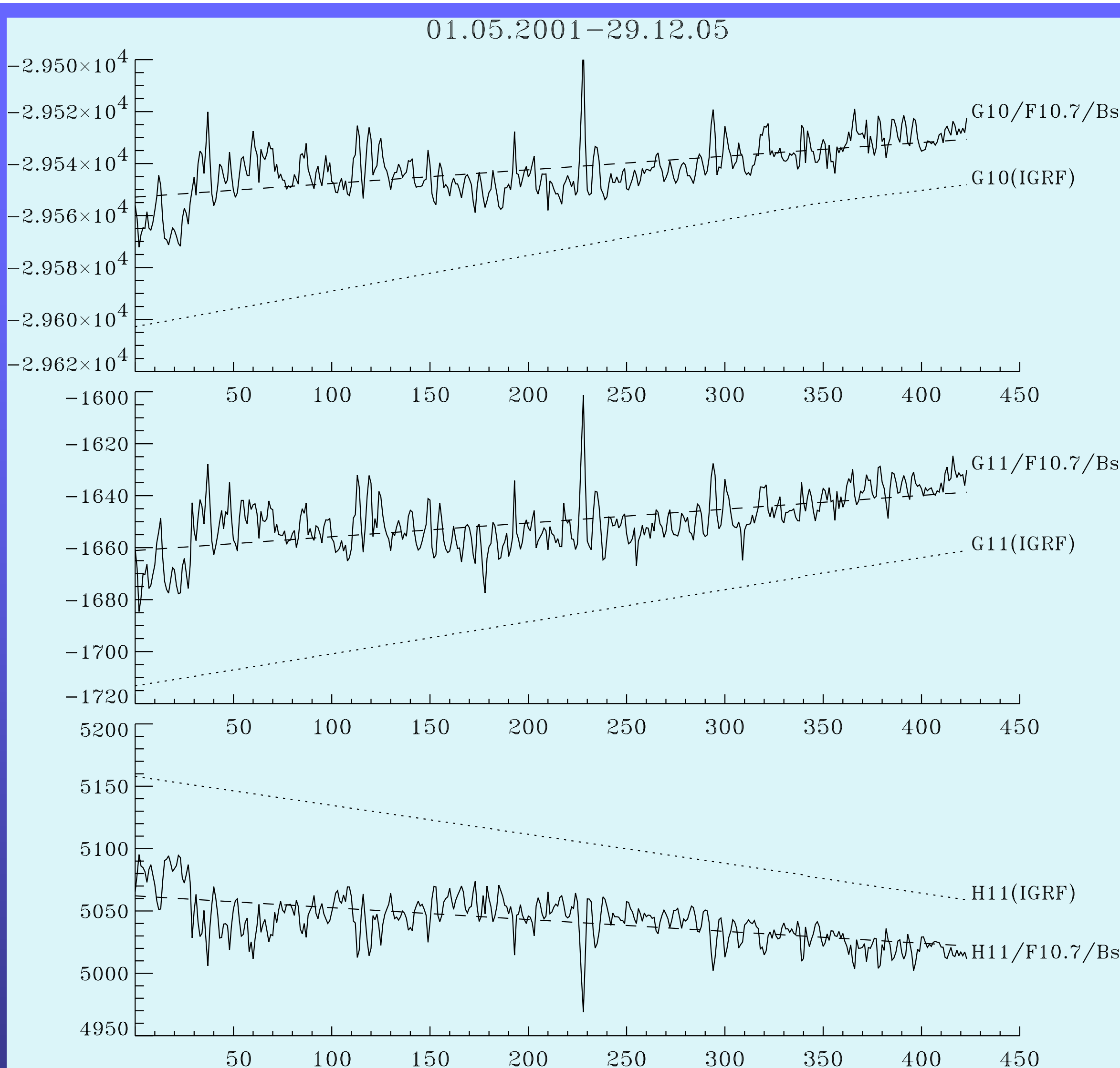




The curves G10, G11, H11 (to the left) display different inclination if compared against those of G10/F10.7, G11/F10.7 and H11/F10.7 (to the right). Apparently, the speed of right curves seems much less than left ones.

In a similar way we have cleared the curves of previous slide (G10/F10.7, G11/F10.7 and H11/F10.7) from influence of parameter ΣV*Bs .

The resulted curves (G10/F10.7/Bs, G11/F10.7/Bs, H11/F10.7/Bs) are shown in the next slide.



Coefficients g_1^0, g_1^1, h_1^1 of author's model (G10/F10.7/Bs, G11/F10.7/Bs, H11/F10.7/Bs - solid lines) cleared of F 10.7 and ΣV*Bs links. The dashed lines are the author's RMS-approximation. The dotted lines present the same coefficients of IGRF model (2000-2005).

Using this slide, it is possible to compare the decrease of the IGRF model coefficients and our coefficients.

Such comparison is resulted in the following Table:

Coefficients	Rate of changing per year (nT/year)	
	IGRF (2000-2005)	Reported model
g^0_1	11,59	4,70
g^1_1	11,04	4,75
h^1_1	20,97	8,50

Let me summarize our results:

(1) the IGRF models are not completely clear of influence of external sources.

In particular, the IGRF models do not account for impacts of the ionosphere and magnetosphere ring current sources, as well as magnetotelluric currents generated in the Earth's crust and upper mantle.

(2) The above mentioned sources play a significant role in temporary dynamics (the first derivative) of IGRF model's coefficients. Apparently, the nature of this process is connected with solar activity.

(3) Our research shows that the geomagnetic field from the ionosphere ring currents, varying due to change of conductivity of an ionosphere under influence of wave radiation (parameter F10.7), plays here the basic role.

(4) With proper account for mentioned above sources, the decrease of a dipole magnetic field for time interval of 2000-2005 yrs is estimated as ~5-10 nT/yr.

This value is 2.5 times less than it is predicted from IGRF models.

Conclusions

- Models of the main magnetic field of the Earth (for example, IGRF) include a part generated by the external source - *E*-layer current of the ionosphere.
- This external part, remaining much less than the internal part, renders significant influence on estimated velocity of the Main Geomagnetic Field (MGF).
- With proper account for this external part, the speed of MGF decrease is estimated as 5-10 nT/yr.

So, the our MAIN RESULT is:

It means that we have 3000-6000 years till “doomsday” , instead of 1500 as affirms in some publications.

Thank you for your attention

and

we wish you to sleep easy !

The End

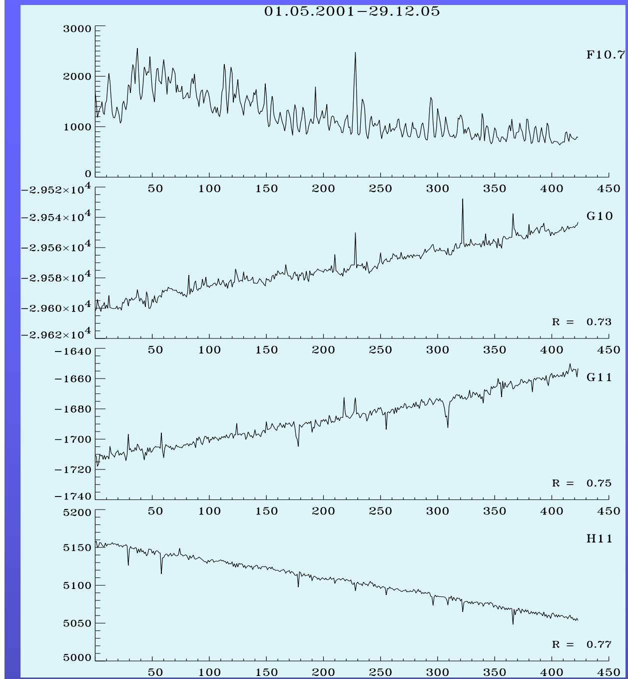
Magnetic field **H** (z, φ, λ, t) is created by various sources inside and outside of the planet and can be presented as a sum of two parts - internal ($\mathbf{H}_{int}$) and external ($\mathbf{H}_{ext}$):

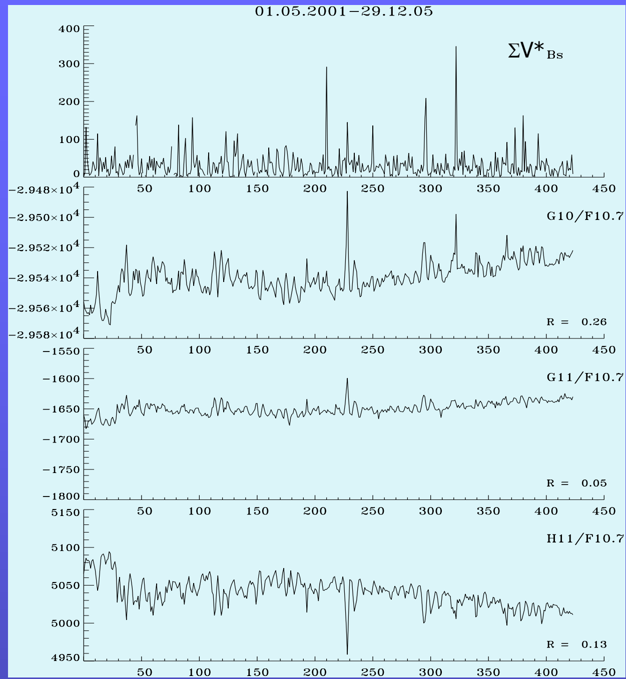
$\mathbf{H} = \mathbf{H}_{int} + \mathbf{H}_{ext}$, where

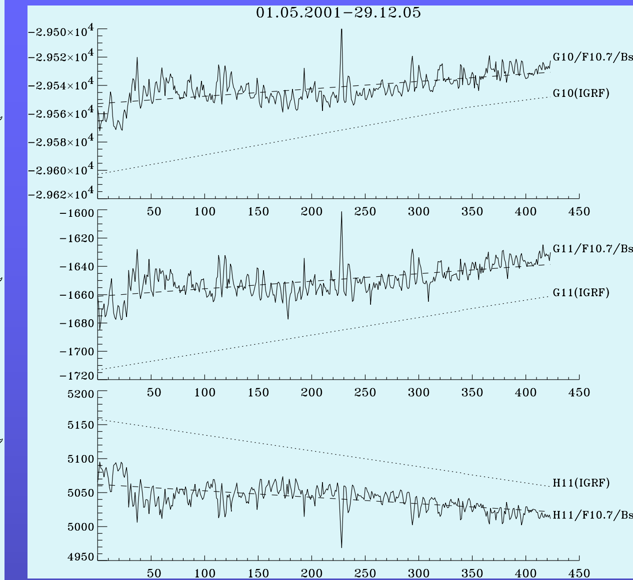
H_{int}	Time range	Spatial range	Signal range
Core dynamics and geodynamo processes (Main field)	static	3000 km to global	< 65000 nT
	3 months to decades	2500 km to global	±200 nT/yr
Lithospheric magnetisation (Lithospheric field)	decades to static	300 km to 3000 km	±25 nT
3-D mantle conductivity	1.5 hours to 11 years	300 km to global	±200 nT
Ocean circulation	12 hours to 2 years	600 km to 10000 km	±5 nT

H_{ext}	Time Range	Spatial Range	Signal Range
Ionosphere-magnetosphere current systems	0.1 sec to 11 years	1 km to global	B-field: ±1000 nT E-field: ±0.2 V/m
	10 sec to 3 months	10 km to global	Ion drift velocity: ±4000 m/s
Magnetic forcing of the upper atmosphere	10 sec to 2 years	20 km to global	Plasma density $1\cdot10^{8}$ m^{-3} to $5\cdot10^{13}$ m^{-3} Air drag: $1\cdot10^{-5}$ m s^{-2}
	10 sec to 3 months	200 km to global	Ion and electron temperature: 1000-100000 K

From Menard et al. (2006)







Three slides together demonstrate: inclinations of curves G10, G11, H11 differ significantly from that ones of curves G10/F10.7, G11/F10.7 and H11/F10.7. It's seems much less, apparently.