The Ninth Workshop
Solar Influences
on the Magnetosphere, Ionosphere and Atmosphere

The solar dynamo and the relation of magnetic fields with different scale sizes.

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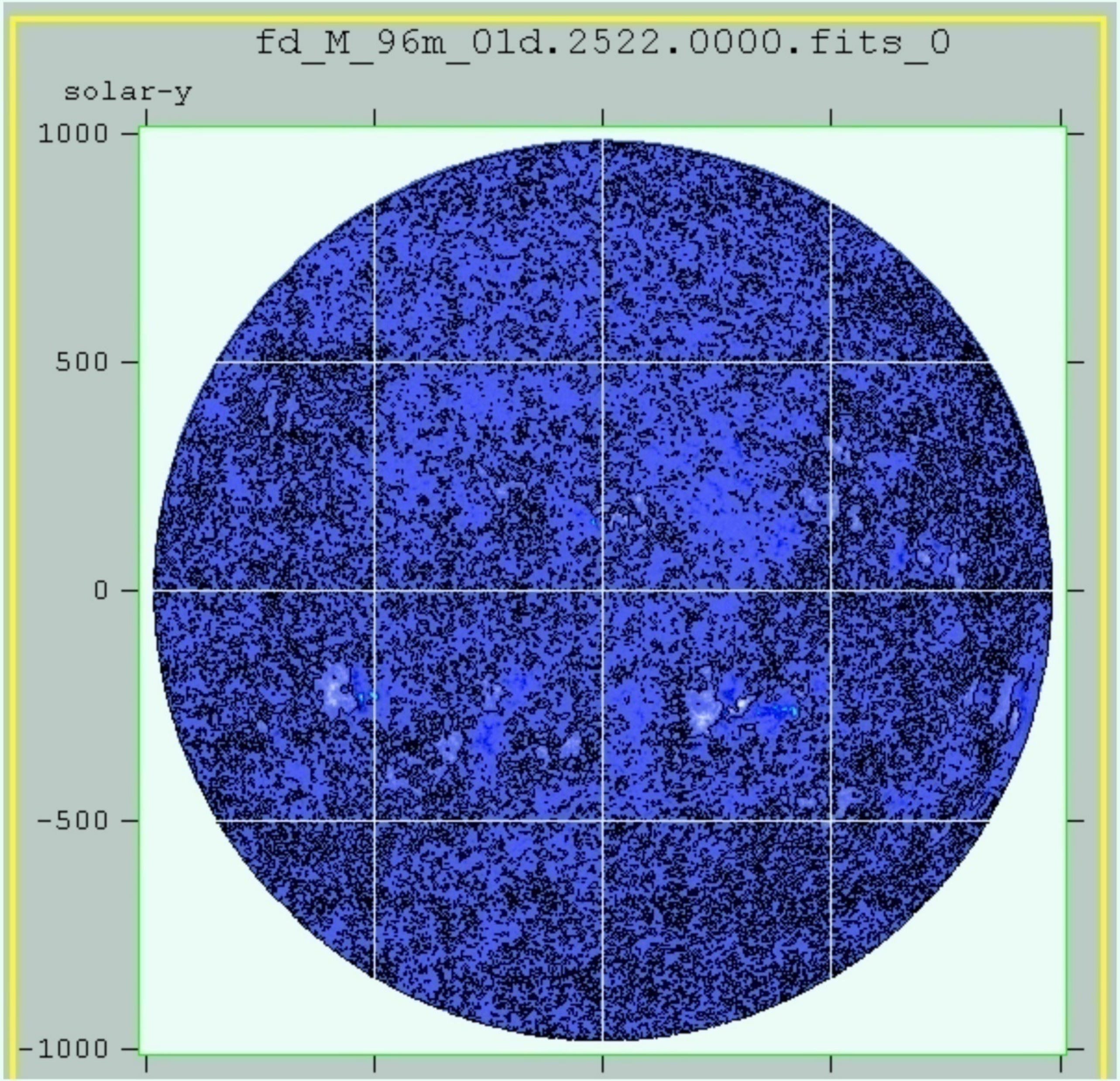
Dynamo theory suggests that there are two types of solar dynamo, namely the conventional mean-field dynamo, which produces large- and small-scale magnetic fields involved in the activity cycle and also the small-scale dynamo which produces a cycle independent small-scale magnetic field. The relative contribution of the two mechanisms to solar magnetism remains a matter of scientific debate, which includes the opinion that the contribution of the small-scale dynamo is negligible. Here we consider several tracers of magnetic activity that separate cycle-dependent contributions to the background solar magnetic field from those that are independent of the cycle. Background fields are very poorly correlated with the sunspot numbers and vary little with the phase of the cycle. In contrast, the stronger magnetic fields demonstrate a pronounced cyclic behavior.


fd_M_96m_01d.2522.0000.fits_0
solar-y
1000
500
0
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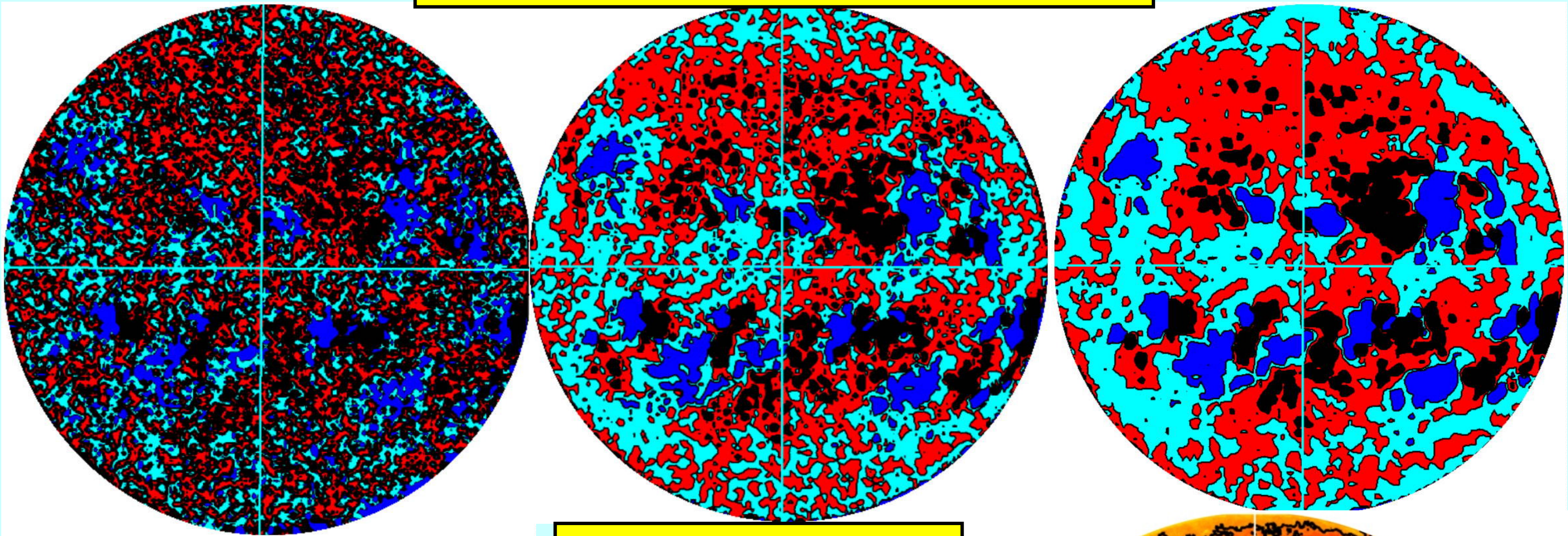
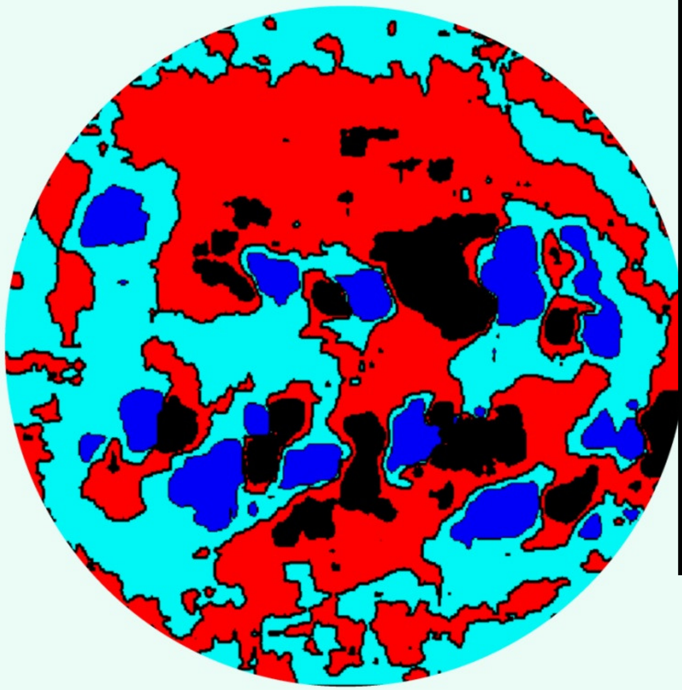
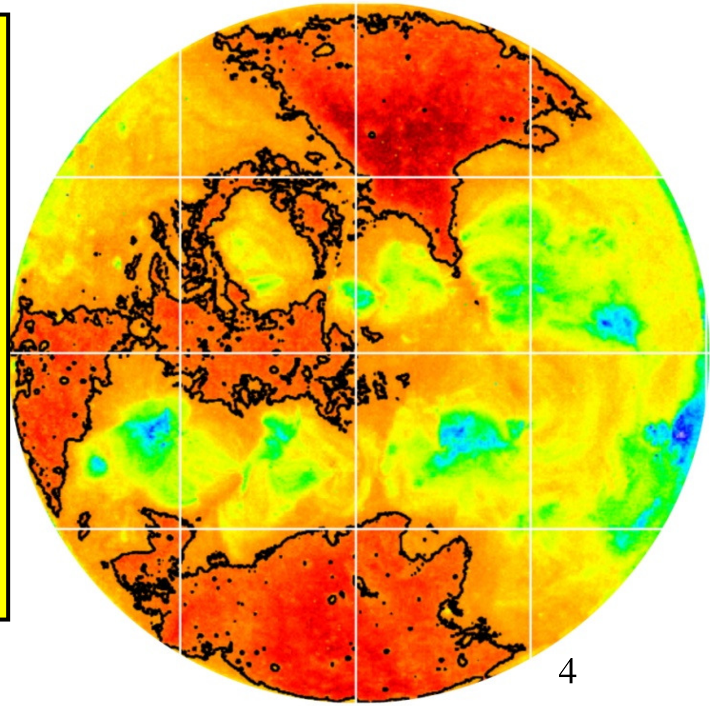
D=10, 20, 40, 80 pixels

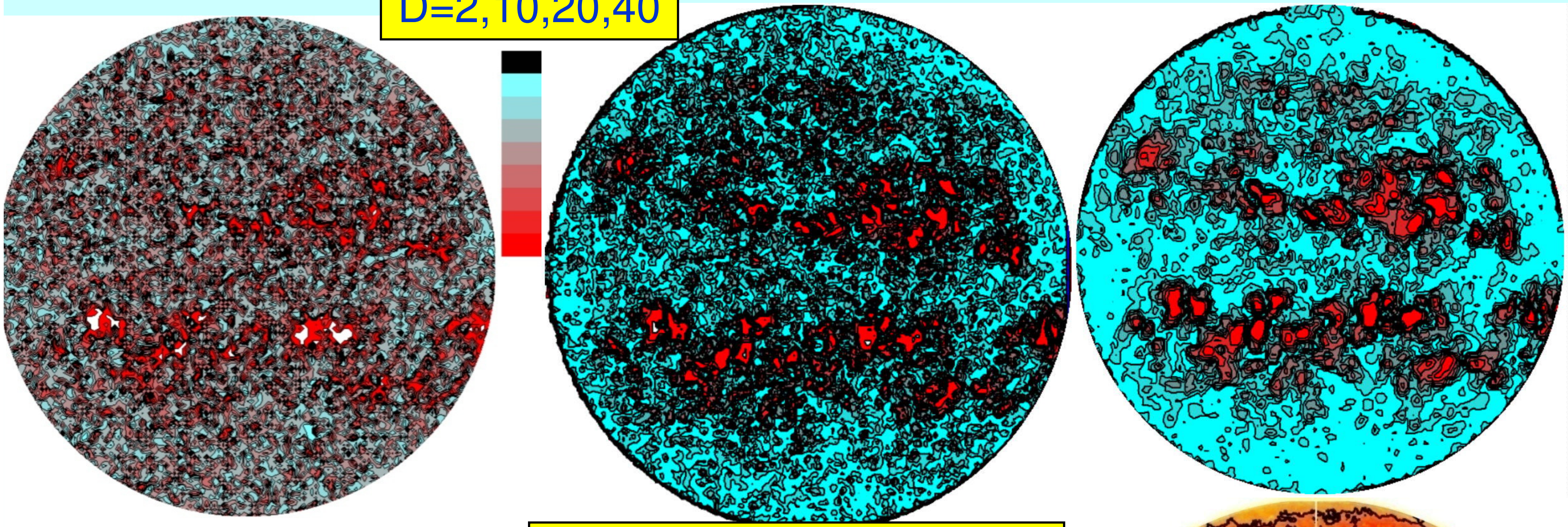


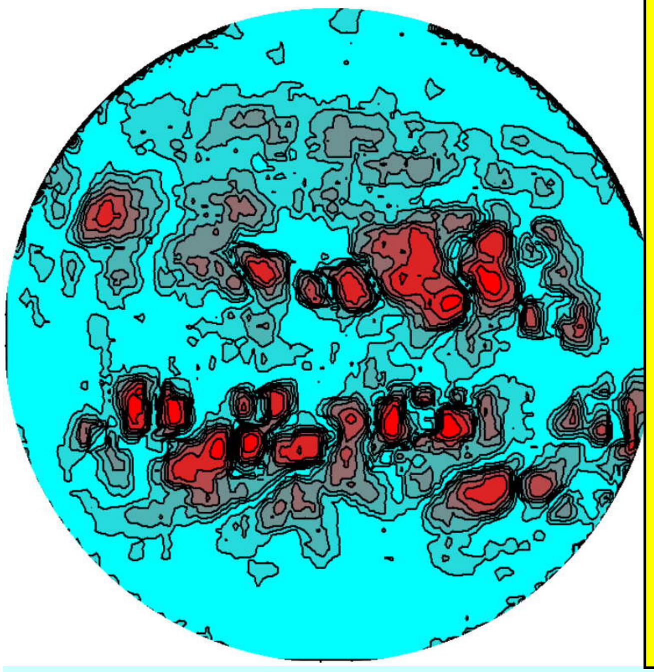


1. The best match of CH contours and magnetic field structure is obtained at averaging over 40-80 pixels (80—160”).
2. CH is part of a large area of mainly positive field <10 G with active regions and included fields of opposite sign.



D=2,10,20,40

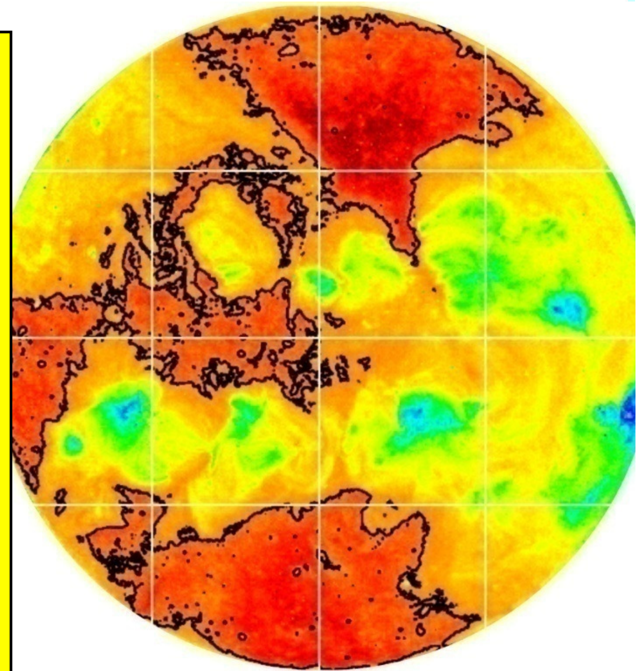




Index of unipolarity
IU=|<B>|/<|B|>.

The magnetic field of the Sun in extremely intermittent.
Only the averaging over 40-80” reveals that +0.3-0.4, i.e., 60-70% of the total flux does not close in the immediate vicinity.

This is where CHs are located



Currently, there are two databases of high-resolution observations made on the same type instruments.

SOHO/MDI

Operating time 1976-2011, pixel size 1.98 arcsec, single measurement noise 26.4 Mx cm-2

SDO/HMI.

The operating time from 2010. Pixel size 0.505 arcsec, single measurement noise 10.2 Mx cm-2

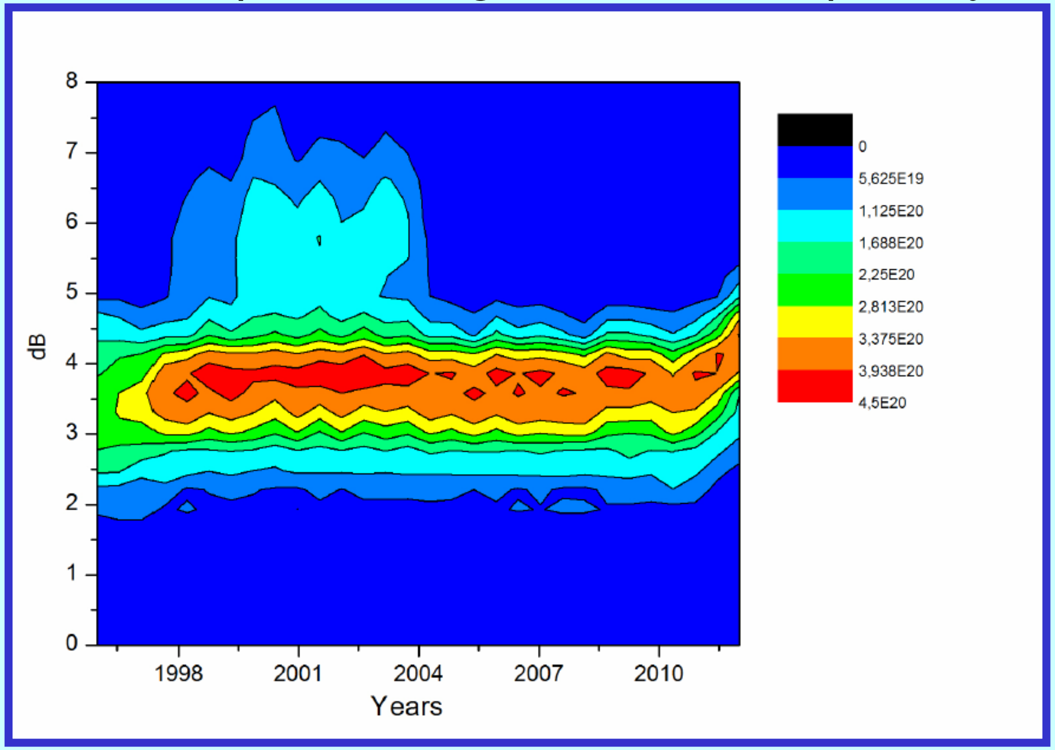
Magnetic field by MDI is 1.4 times higher

Scherrer *et al.*, 1995, Scherrer *et al.*, 2012; Schou *et al.*, 2012, Liu et.al (2012)

For our task of analyzing the cyclic variation of magnetic fields of different intensity, it is important to have long, uniform and unistyle observations. Therefore, we first discuss the results based on the MDI data, and then perform a similar analysis according to HMI.

Analyzing MDI data

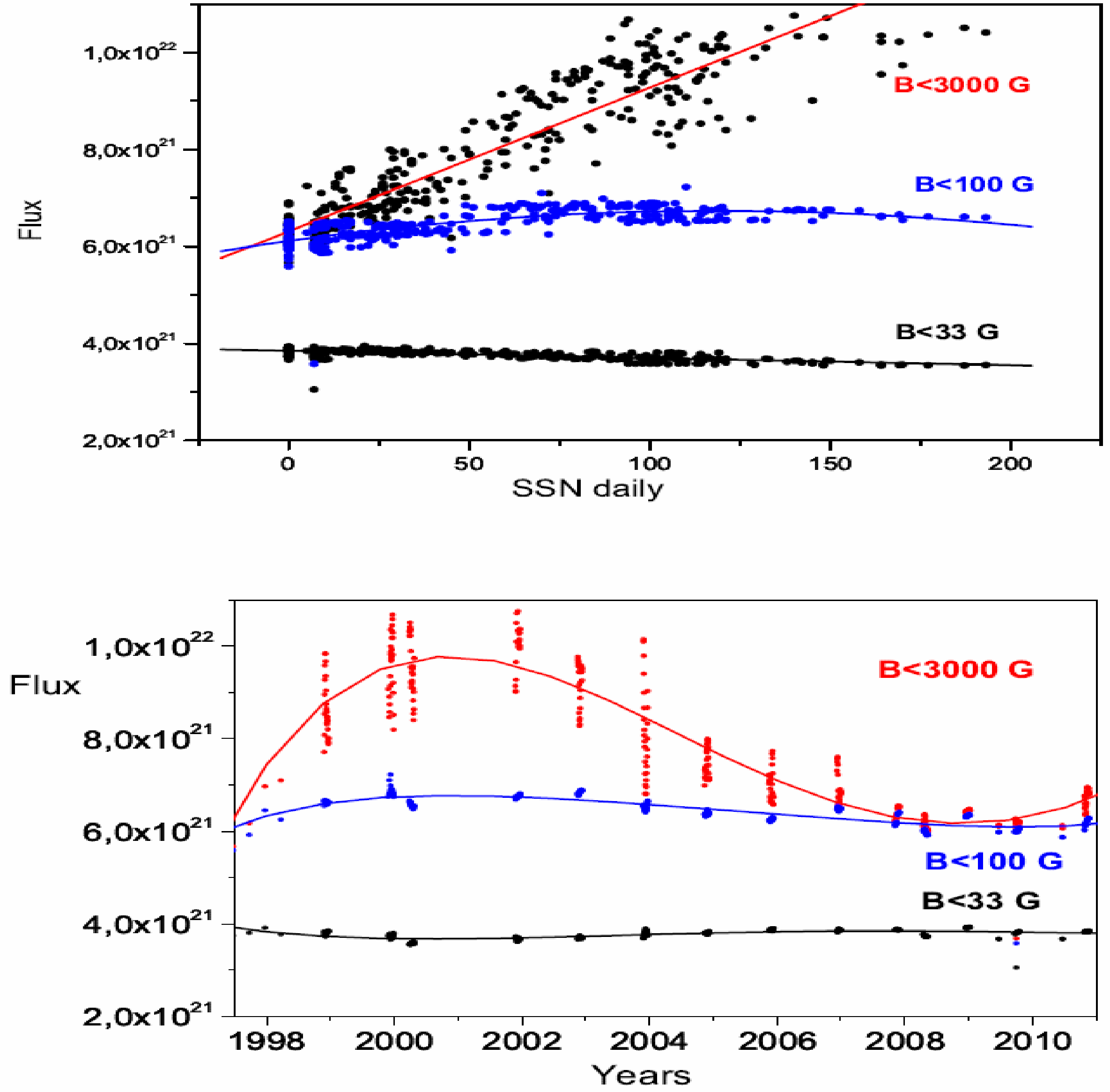
We begin by assessing the contribution of fields of different intensity to the total flow. The summation of the absolute values of the fields in the range from 1 to 3000 Mx cm^{-2} with a step in the logarithm of the quantity $\Delta \ln B = 0.1$



The main contribution to the total flux is given by fields ~ 100 G. This contribution is almost independent of the phase of the cycle. At the maximum of the cycle, the contribution of stronger fields is enhanced, but it is still lower than for fields less than 100 Gs.

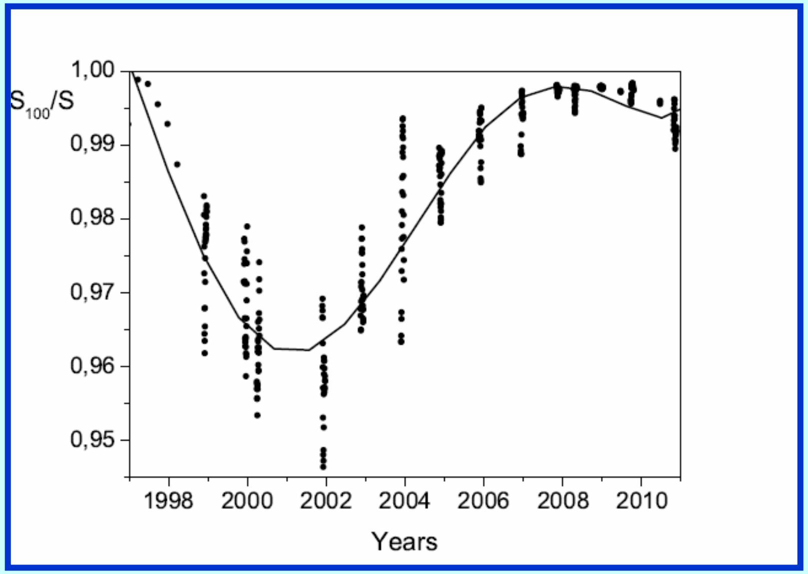
This figure summarizes the absolute values of the fields limited by the upper limit of 33, 100, and 3000 Mx cm^{-2}, depending on the number of spots on a given day and the date according to MDI data.

The flux of weak magnetic fields is almost independent of the phase of the cycle. In contrast, the total flux is clearly connected with the phase of activity cycle. The contribution of fields <100 Mx cm^{-2} determines almost 100 % of the total magnetic flux at the minimum of the cycle (2008-2010) and only about 50 % at the maximum (200-2002).

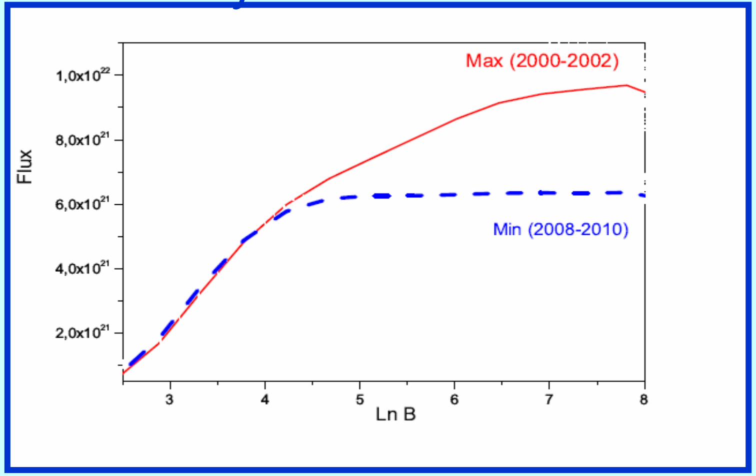


The relative areas occupied by the magnetic fields of intensity <100 Mx cm^{-2} are, respectively, 99.3 % at the minimum and 94.4 % at the maximum of the cycle

For fields of about 100-150 Mx cm^{-2} the accumulated flux curves are more or less independent on the cycle phase. In contrast, for stronger fields, the magnetic flux at the maximum is much larger than at the minimum



The relative share of the area occupied by weak fields



Accumulated flux for weak and strong fields at the minimum and maximum cycle

Thus, we can conclude that there are two populations of magnetic fields. The weak fields of magnitude less than 100 Mx cm^{-2} apparently arise as a result of a small-scale subsurface process, while the stronger fields are connected with the cycle and are generated by the classical mean-field solar dynamo.

HMI data analysis

The entire calculation procedure was the same as above. The main differences are as follows

A) All calculations were carried out for all days of observation without omissions (ie 2226 days). Then the data were averaged over 30 days. This provides a more uniform temporal resolution on new drawings .

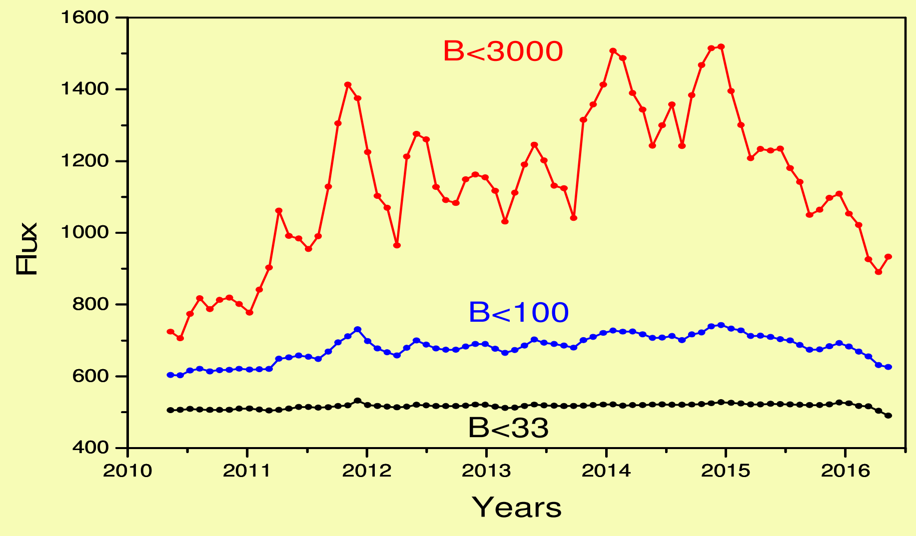
B) The flux was calculated not over the entire disk, but only inside the central circle $R<0.7\,R_{\odot}$ (That is, at a positional angle $\theta< 45°$).

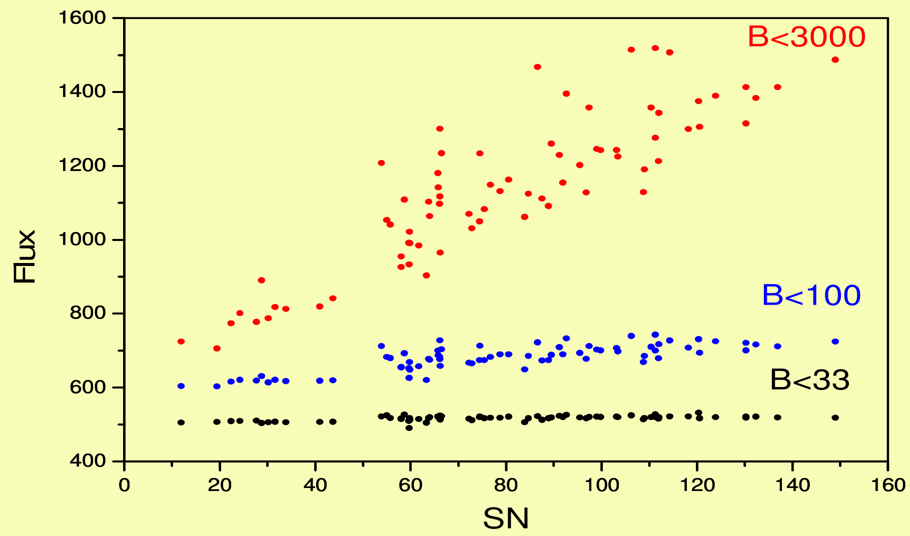
C) To reduce the possible impact of the projection, all data were divided by $\cos\theta$.

D) A correction was introduced for changing the apparent diameter of the Sun's disk due to the motion of the Earth in orbit.

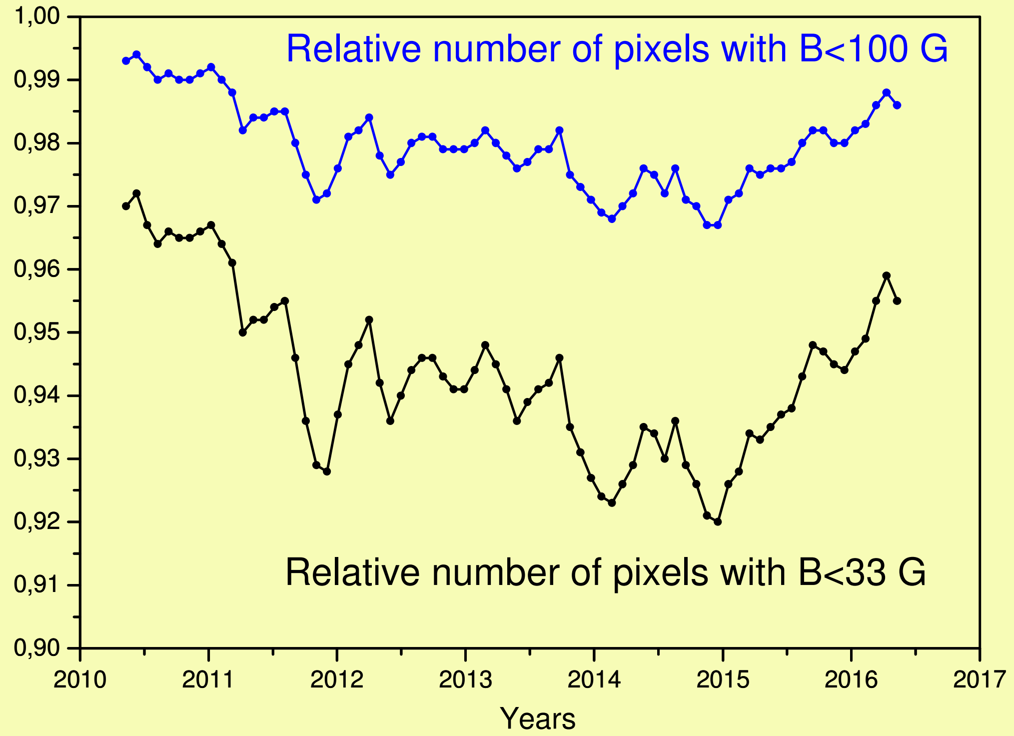
E) All flow values are expressed in units of 10^{19} Mx.

This figure summarizes the absolute values of the fields limited by the upper limit of 33, 100, and 3000 Mx cm^{-2}, depending on the number of spots on a given day and the date from the HMI data. The main results are the same as those obtained by MDI

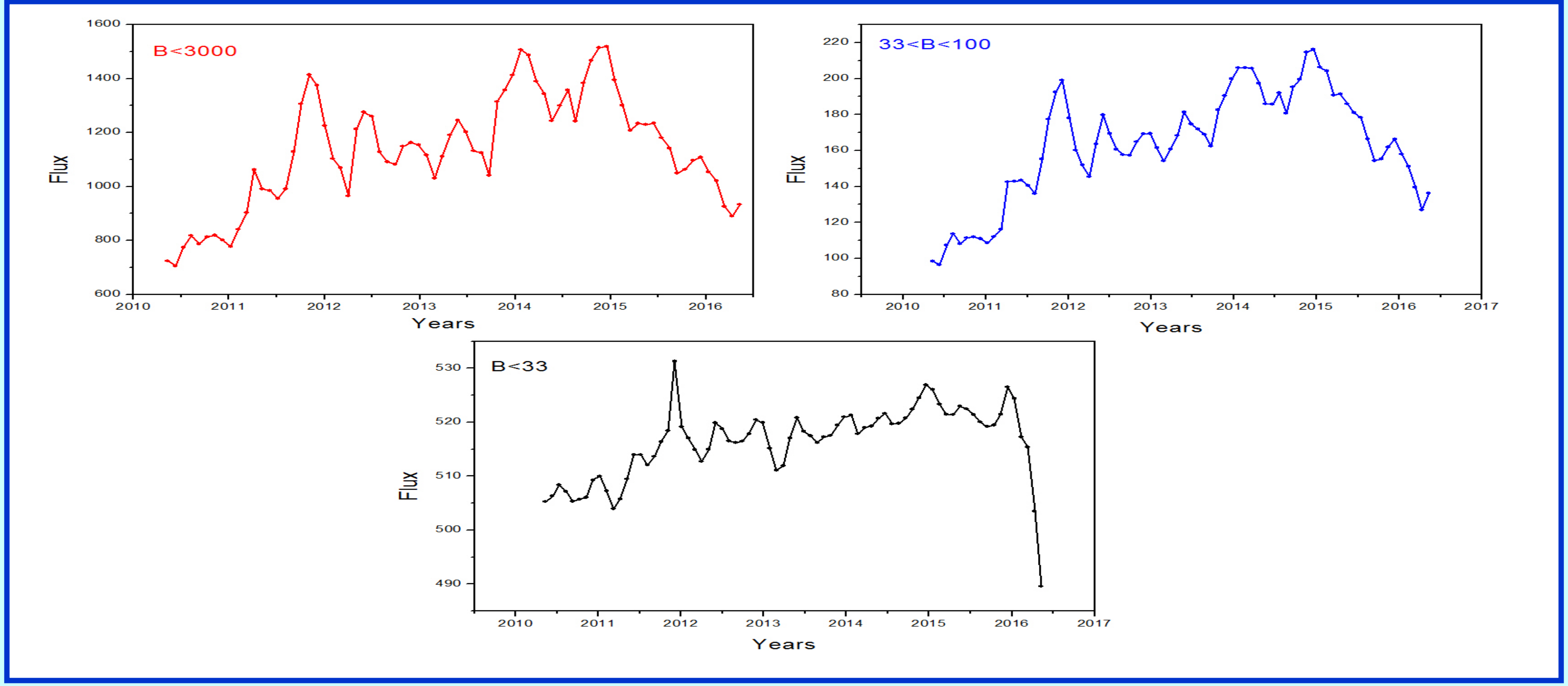




The relative share of the area occupied by fields less than 33 and 100 Mx cm^{-2}

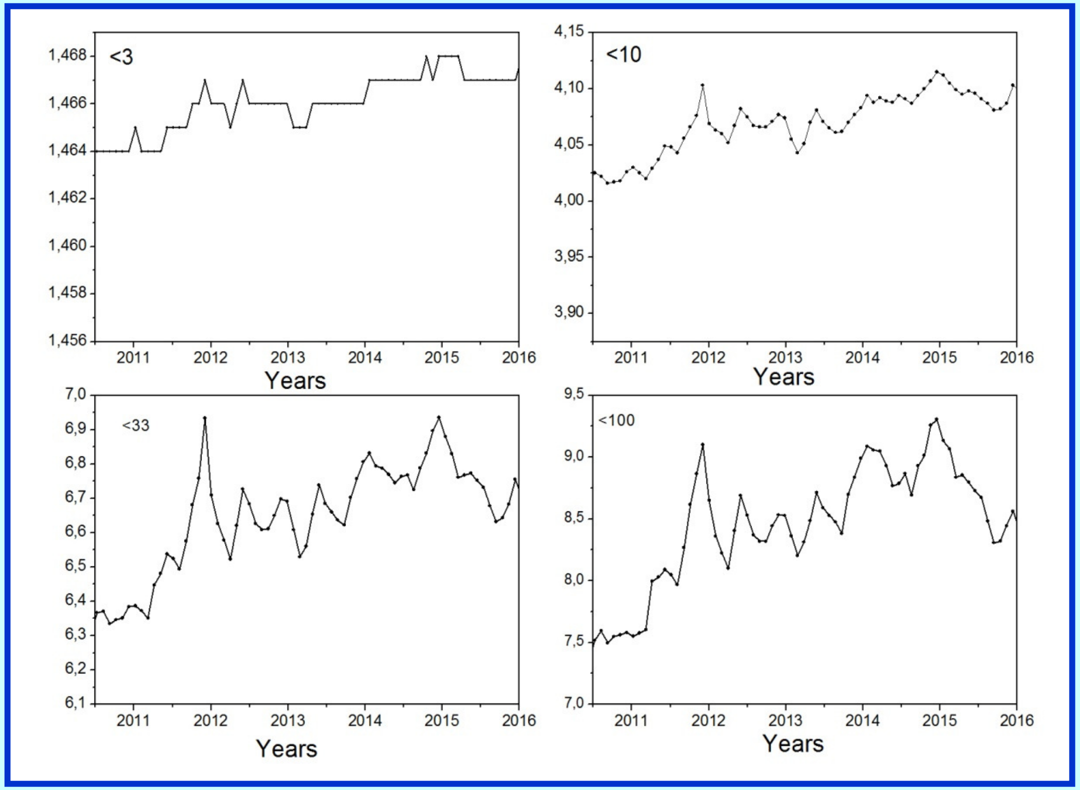


Cyclic variation of weak fields



If we take into account that the flux of the fields <33 Mx cm^{-2} enters the flux of fields <100 Mx cm^{-2}, it turns out that the flow of fields in the range 33-100 Mx cm^{-2} changes approximately the same way as the total flux. And yet the flux of a weaker field B <33 Mx cm^{-2} is greater than the flux of moderate fields 33 <B <100 Mx cm^{-2} Why?.

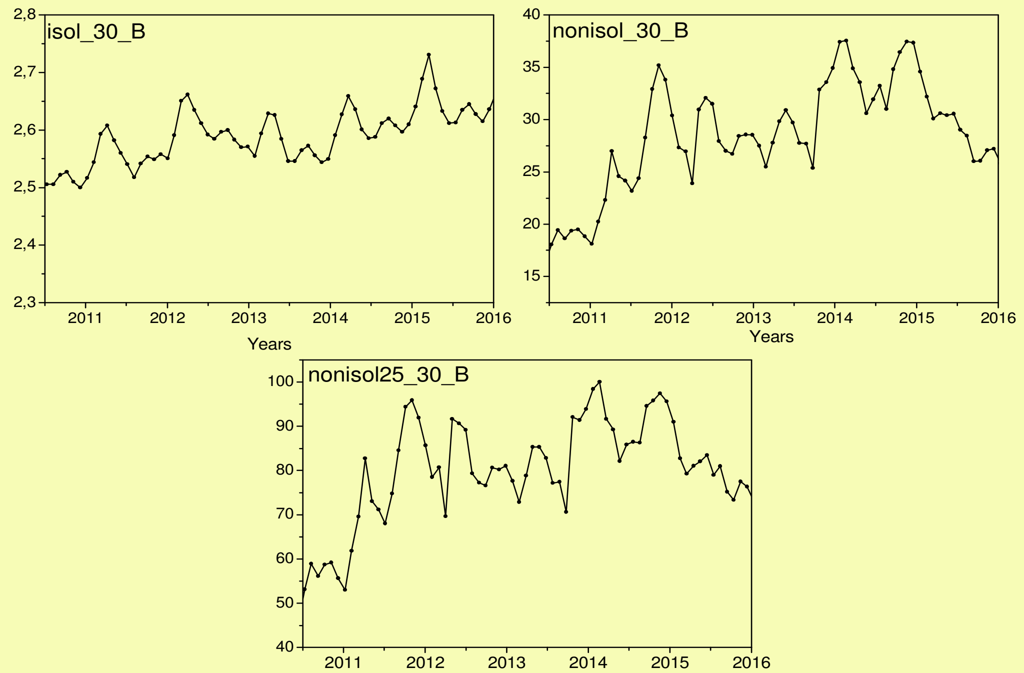
Apparently, this is due to the fact that the area of such weak fields is very large. In the calculation of the total flux, the variation of the area can mask the variation of the flux in individual pixels. Therefore, it was worthwhile to see how the average field values change per pixel in these ranges..



This figure shows the average values of the field in pixels with constraints <3, <10, <33, <100 Mx cm^{-2}. Fields with a limitation of <3 and <10 Mx cm^{-2} are apparently determined mainly by noise. Starting from fields with a constraint <33 Mx cm^{-2}, the connection with the cycle is unquestionable

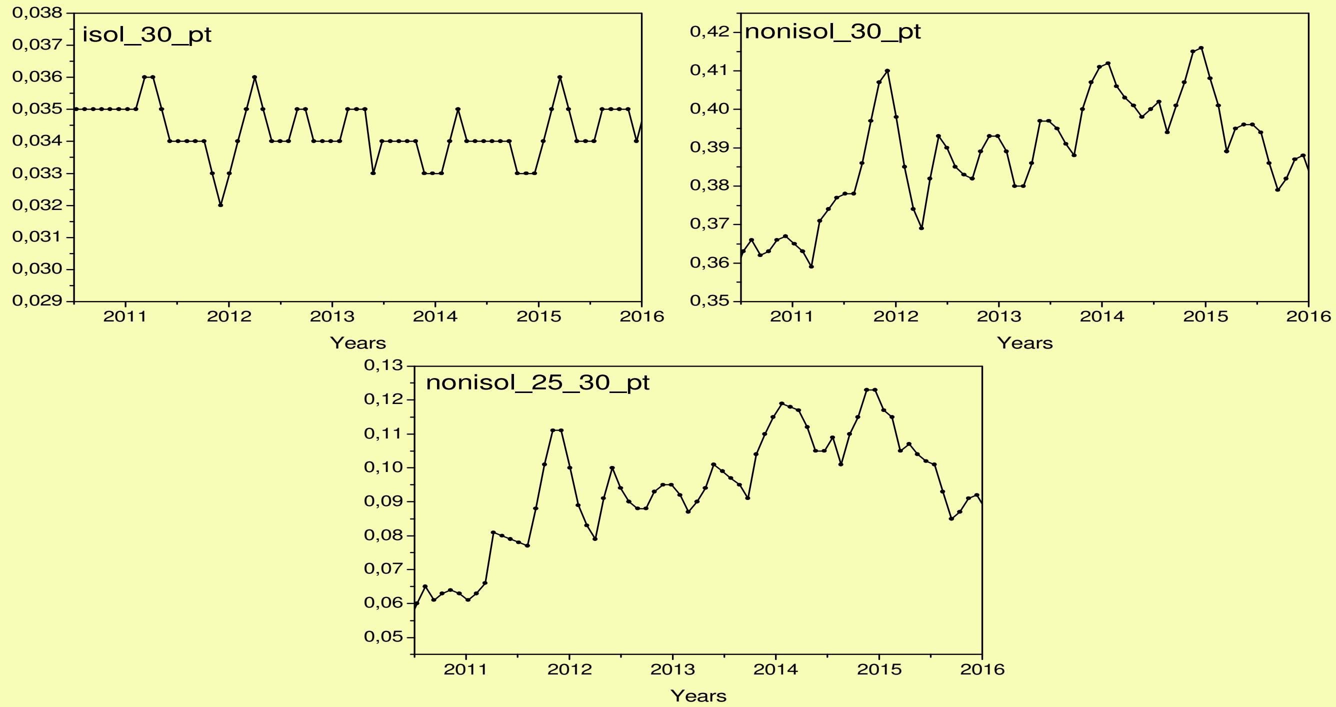
Collective effect in the distribution of weak fields

The average magnetic field in isolated (at least one neighboring pixel has the opposite sign with respect to the probe), Simply un_isolated (all four surrounding pixels have the same sign) and un_isolated 25 (all 24 surrounding pixels have the same sign.



Isolated pixels have an extremely small field and in behave roughly the same as noise pictures with a limitation of <3 and <10. In pixels surrounded by pixels of the same sign, the field increases sharply.

Относительная площадь на диске, занимаемая пикселами этих трех типов



The relative area of isolated pixels is virtually independent of time. Pixels surrounded by 4 pixels of the same sign form a very significant population and, what is most significant, actually coincide with the curve of solar activity. Pixels, surrounded by 24 pixels of the same sign, show approximately the same time dependence, but they are found somewhat less frequently.

Conclusion

Thus, our results show that the dynamo is a single process, carried out simultaneously on different scales. Generally, the generation of the magnetic field is determined by the mechanism of the average field dynamo, which leads to the appearance of an 11-year cycle on a large scale. This mechanism works, starting with the weakest fields, close to the noise limit.

However, the picture is somewhat more complicated. In the cycle, both the average flux per unit area and the relative area occupied by fields of different intensity vary. One process gradually increases the mean values of the fields with the approach to the maximum of the cycle, while the other simultaneously changes the relative area occupied by fields of different intensity.

On this basic mechanism, another mode is imposed, which determines small-scale fluctuations (small-scale dynamo).

And there is another process, leading to an additional concentration of fields to the tensions characteristic of sunspots.

Directly the formation of active regions appears to be associated with this particular mode, which increases the specific intensity of the magnetic field when the pixels of the same sign are combined.

In this case, the initial 11-year cyclicity is manifested in all these modes.


Thank you for your attention !