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The Magnetic Sun from Different Views: A Comparison of the Mean and Background Magnetic Field Observations made in Different Observatories and in Different Spectral Lines

M. L. Demidov, *Institute of Solar-Terrestrial Physics, Irkutsk, P.O.Box 4026, 664033, Russia.*
e-mail: demid@iszf.irk.ru

Abstract. A comparison is made of observational data on the mean magnetic field of the Sun from several observatories (a selection of published information and new measurements). Results of correlation and regression analyses of observations of background magnetic fields at the STOP telescope of the Sayan solar observatory in different spectral lines are also presented. Results obtained furnish an opportunity to obtain more unbiased information about large-scale magnetic fields of the Sun and, in particular, about manifestations of strong (kilogauss) magnetic fields in them.

Key words. Sun: magnetic fields—magnetographs.

1. Introduction

The statement that reliable information on large-scale magnetic fields (LSMF) of the Sun (i.e. the background field (BMF), and the mean magnetic field (SMMF)) is of the utmost importance in the study of many problems in solar and solar-terrestrial physics, is beyond question at present. One of the unassailable reliability criteria of experimental data has always been the reproducibility of these results with different instruments. Therefore, the need for such a comparison of solar data appears also quite explicable. For this purpose, this paper analyzes SMMF observations from different observatories using earlier published data (but collected together), as well as invoking the new observations obtained at the STOP telescope of the Sayan solar observatory (SSO).

A substantial drawback to the present situation of investigations of the solar LSMF is the fact that they are based on observations virtually in only one line-FeI λ 525.0 nm. It has been demonstrated in a large number of publications that it is fruitful to compare high resolution magnetic fields measurements made in different spectral lines. As far as the LSMF are concerned, such investigations were initiated by Demidov (1998). Results of BMF observations in the new lines are presented in following sections.

2. Comparison of the solar mean magnetic field observations

SMMF observations that were initiated over 30 years ago are of significant scientific value for a variety of reasons and in particular for investigations of long-term

Table 1. Comparison of SMMF observations from different observatories: CAO – Crimean astrophysical observatory, MWO – Mt. Wilson observatory, WSO – Wilcox solar observatory, SSO – Sayan solar observatory. R – correlation coefficient, N – number of points.

Reference	Observatories being compared and coefficients of difference	R	N	Time interval
Scherrer 1973	CAO/MWO = 0.76			1968–1972
Scherrer *et al.* 1977	CAO/MWO = 0.8	0.4	464	1971–1974
Kotov & Severny 1983	CAO/MWO = 1.22			1968–1976
	MWO/WSO = 1.76			1975–1976
	CAO/WSO = 2.04			1975–1976
Grigoryev & Demidov 1987	SSO/WSO = 1.51	0.88	228	1980–1982
Kotov *et al.* 1998a	CAO/WSO = 1.25	0.95	26	1991
Kotov *et al.* 1998b	CAO/WSO = 1.2	0.86	732	1991–1993
	SSO/WSO = 0.89	0.85	93	1994
Kotov *et al.* 1998c	WSO/CAO = 0.43			1973–1976
	WSO/MWO = 0.59			1975–1982

variations in global magnetism and solar rotation. Since SMMF observations are carried out at several observatories, it is natural to question the degree of quantitative correspondence of different observational series. Some relevant information from different publications is presented in Table 1. It turns out that the degree of correlation of the series and the amount of their systematic difference depend on the particular combination of the series being compared and also change with the time. There can be several reasons for the existence of such systematic differences: calibration, instrumental weighting functions, methods of zero level monitoring, etc. Also, one of the serious reasons is most probably the difference of parameters of photometers in magnetographs at different observatories and, as a consequence, a different character of signal attenuation in strong fields. Such an explanation is supported by, for example, the following fact. According to Table 1, the coefficient of difference of the SMMF observations at SSO and WSO during 1982–1984 was: $H_{\rm SSO}/H_{\rm WSO} = 1.51$. A comparison of the data from these observatories for 1993–1997 gives the following relationship (number of points $N = 487$, $R = 0.71$):

$$H_{\rm WSO} = -5.4(\pm 1.4) + 0.91(\pm 0.03) \times H_{\rm SSO}, \tag{1}$$

showing that the degree of correspondence of the observational series has improved considerably. The most probable reason for a change in the character of correspondence of the data from the two observatories implies that in 1991 in the course of a STOP upgrade the photometer parameters were modified significantly: the mean distance of the slits from the line center became 4.2 pm instead of 8.2 pm (it will be recalled that at WSO and at Mt. Wilson this value is 4.4 pm, and at Crimea it is 6.2 pm). As a consequence, the SSO measurements has become more sensitive to the saturation effects in the strong magnetic fields. But more convincing evidence for the manifestation of strong fields in the LSMF observations follows from an analysis of the SMMF and BMF observations in different spectral lines.

Table 2. Results of correlation and regression analyses of the BMF observations in different combination of spectral lines. The parameters of the linear regression equation $H_{\text{line Y}} = A(\pm\Delta A) + B(\pm\Delta B) \times H_{\text{line X}}$ were calculated using the method of reduced major axis.

Line Y	Line X	N	A	ΔA	B	ΔB	R
525.0	513.7	365	37	27	0.38	0.01	0.87
524.7	513.7	249	44	37	0.46	0.02	0.77
525.0	525.1	635	−6	23	0.58	0.01	0.86
524.7	525.1	522	−5	14	0.65	0.01	0.95
525.0	524.7	4506	1	2	0.83	0.005	0.89

3. BMF observations in different lines, and their analysis

Observations of the background magnetic fields at STOP are carried out with an angular resolution of (usually) 120 seconds of arc, with the time difference between magnetogram recordings in different lines of about 1.5^h. A special investigation of the influence of such a time difference on the results has shown that it can be considered negligible. The lines used in the observations are: λ 513.7 nm NiI (Lande factor g = 1), λ 524.7 nm FeI (g = 2), λ 525.02 nm FeI (g = 3), and λ 525.06 nm FeI (g = 1.5). The mean position of the photometer slits relative to the line centre was 4.2 pm in all cases.

Results of correlation and regression analyses of the BMF observations in different combinations of spectral lines are summarized in Table 2. It is evident from the data in this table that the BMF observations in different lines are correlated very well with each other, but they differ greatly in amplitude of the measured strengths. If it is assumed (Ulrich 1992) that the effects that distort the magnetograph signal have no (or only a minor) influence on the observations in lines with a small Lande factor, for example, in our case in the line λ 513.7 nm NiI with g = 1, then one has to recognize that measurements in the most frequently used line λ 525.02 nm FeI give strengths underestimated by a factor of 3, not by a factor of 1.8 as believed previously. It will be recalled here that according to (Ulrich 1992) and (Wang & Sheeley 1988) this factor even might be 4. It is worthwhile to note, however, that the lines λ 513.7 nm NiI and λ 525.02 nm FeI, as well as the lines λ 523.3 nm FeI and λ 525.02 nm FeI, used by Ulrich (1992), are not magnetic ratio lines (as a well-known pair of lines λ 524.7 nm FeI and λ 525.02 nm FeI).

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