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East-West Asymmetry in the sunspot number distribution on the basis of different sunspots catalogues

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Abstract
The east-west asymmetry of the number of sunspots has been analyzed on the basis of the Debrecen Photoheliographic Data (DPD), the single spots of Greenwich Photoheliographic Results (GPHR), and the Sunspot Feature Catalogue (SFC). The DPD and SFC do not show E-W asymmetry in the number distribution of the spots for the spots with area of greater than 20 millionth of the solar hemisphere (MSH). The GPHR shows large E-W asymmetry. Its rate is increasing from center to limb while the area of the affected spots is also increasing from 10 to 50 MSH. The East-West asymmetry of the number of spots can be detected for small spots (<20 MSH) in all the three catalogues but its rate depends on the studied catalogue.
Keywords: *Sun: East-West asymmetry, Sun: Sunspot area distribution*

1 Introduction

The east-west asymmetry of sunspot groups was discovered by Maunder (1907). She found that there were more groups on the eastern than on the western half of the solar disc and also found eastern excess in the total area of spots. This "east effect" has been investigated by numerous astronomers since then, but the results are not concordant.

Maunder found the asymmetry by using of the data of one solar cycle (1889-1901) of the GPHR. However, Pajdušáková (1969) showed that there were cycles with western surplus of the number of sunspot groups in the GPHR, too.

This asymmetry was investigated on the function of the phase of development of groups (classification) (Bartsch, 1973) and the phase of the solar cycle (Pajdušáková, 1969).

Archenhold (1940) was the first who studied the distribution of individual spots to avoid the difficulties arising from the complexity of groups. He found that near the limb the asymmetry is about 20%. Gleissberg (1945) also counted individual spots on the Mount Wilson drawings. He established that the preceding spots show western excess while the following spots eastern excess.

Many hypothesis were born to explain this phenomenon: the unfavorable effect of the planets on solar activity (Maunder, 1907), the effect of faculae (Sawyer and Haurwitz, 1972), the inclination of spot axis (Minnaert, 1946), etc.

Earlier we investigated the E-W asymmetry of the spot number distribution taking into account how this distribution depends on the spot area using the data of the GPHR and DPD (Mező et al., 2005). Recently the SFC catalogue has become available, which contains the position and area of every observable sunspot similarly to DPD and the printed version of the GPHR (for the years 1884-1916). The SFC catalogue (Zharkova et al., 2005) was made automatically using the full disk continuum SOHO/MDI images. The SFC may help to decrease some possible effects affecting the detection E-W asymmetry.

The MDI images are free from the effects of the terrestrial atmosphere. The method of sunspot detection and area measurement is different from the previous ones. The larger time resolution may decrease the possible effect of time gaps.

2 The Observational Material

The data was taken from the DPD for the years of 1986-1989 and 1993-1998, from the electronic version of the GPHR (ftp:// ftp.ngdc.noaa.gov/STP/ SOLAR_DATA/SUNSPOT_REGIONS/GREENWICH/)

for the years of 1874-1974, and from the SFC for the years of 1996-2004. The electronic version of the GPHR gives only the position and area of the spot groups but it was also possible to select the single spots with the help the given classification of the groups.

The DPD contains about 140000 individual spot data, the SFC contains about 364000 individual spot data, and the GPHR contains about 47000 single spot data in the above mentioned time intervals.

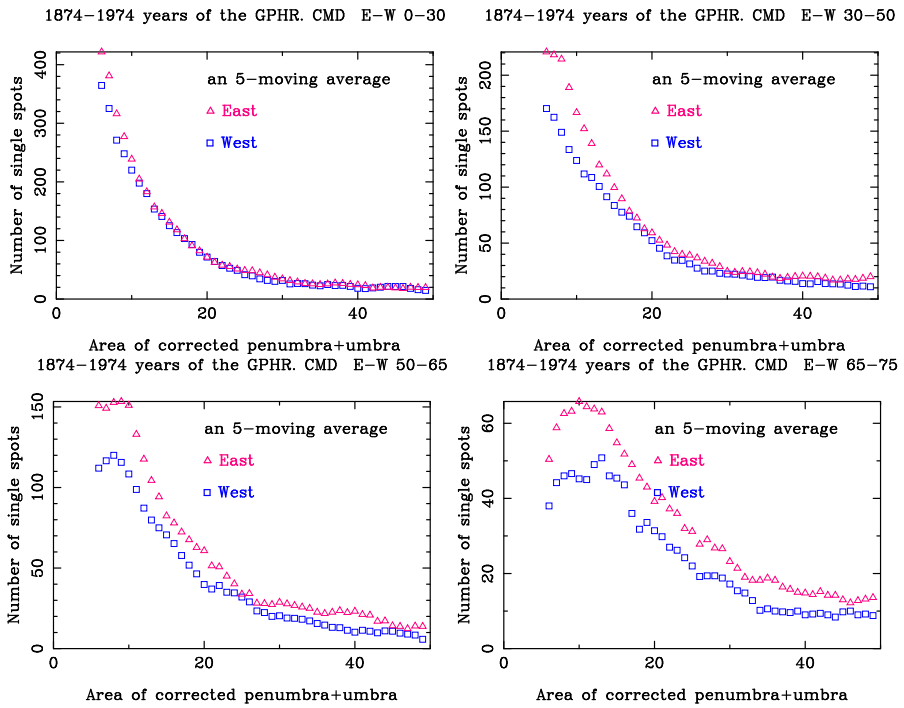

Figure 1: *Distribution of the number of the single spots of GPHR as a function of the corrected sunspot areas from the central meridian to the limb.*

The spatial resolution of the observations of the DPD and the GPHR is about 1″ and of the SFC is about 2″.

The time resolution of the DPD and GPHR is one day and the time resolution of the SFC is about 6 hours.

3 Distribution of the Number of Spots as a Function of the Corrected Sunspot Areas

We divided the solar hemisphere into zones from East to West. The zones were chosen symmetrically to the central meridian. The eastern zone was $[-L, -L + \Delta L]$ and the western zone was $[L - \Delta L, L]$ where L is the central

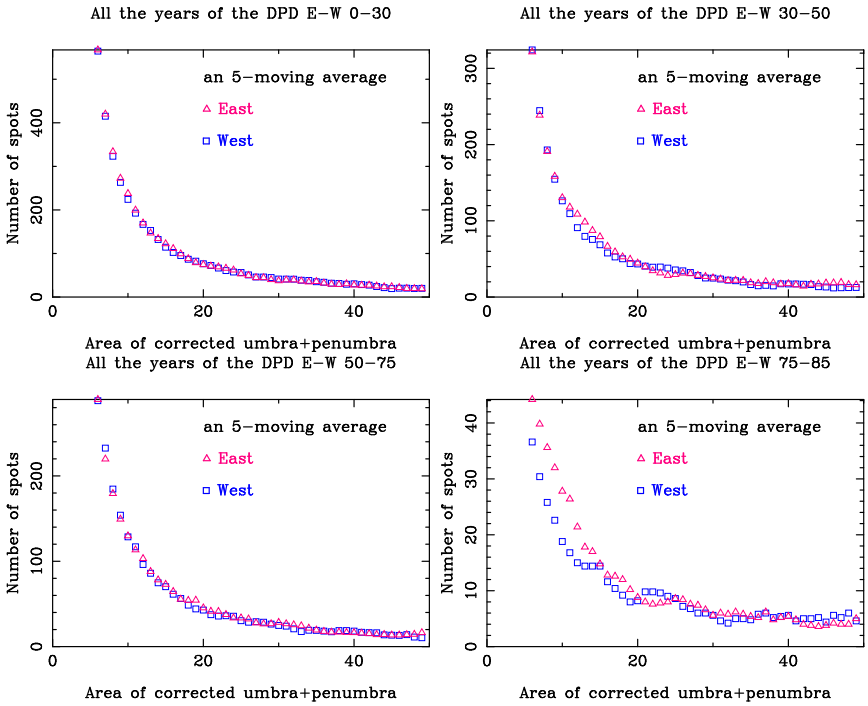

Figure 2: *Distribution of the number of the spots of DPD as a function of the corrected sunspot areas from the central meridian to the limb.*

meridian distance. We counted the spots in each zone with a given corrected area.

These numbers were displayed against the corrected area for the eastern and western halves on the same figure.

The spots of the corrected sunspot area being smaller than 6 millionth of the solar hemisphere ($A_c < 6\,MSH$) were omitted. In the case of the DPD and the GPHR it is to eliminate any visibility effect due to the tiny spots and solar pores but in the case of SFC it is to choose spots with more than two pixels near the limb in the observed images.

The results derived from the different catalogues are somewhat contradictory.

The GPHR shows large E-W asymmetry (Figure 1). The distribution of the GPHR single spots shows an increasing eastern excess from center to limb while

the maximum area of the affected spots is also increasing from 10 to 50.

The large spots ($\sim A_c > 20\,MSH$) of the DPD (Figure 2) and the SFC (Figure 3) do not show any difference between their eastern and western distribution in any zone pair. However, in the case of spots of $A_c \leq 20\,MSH$ the results are different.

The small spots of the DPD ($\sim A_c \leq 20\,MSH$) have no E-W asymmetry between 0° and 75° but they show a small eastern excess observable in the zones very near the limb between 75° and 85°.

The small spots of the SFC have a small eastern excess in the zones near the central meridian and no asymmetry or rather western excess in the zones near the limb.

4 Discussion

The DPD and SFC catalogue give the same result for the spots with area of greater than 20 MSH: there is not E-W asymmetry in the number distribution of the spots.

This questions the result derived from GPHR which shows eastern excess for spots of area >20 MSH.

Thus, the simple hypothesis of the inclination of spot axis cannot be maintained because in this model the inclination of spot axis independent of spot size.

The method used for calculation of the angle of spot axis by Minnaert (1946) is also questions his simple model. Minnaert used the corrected total spot area of the Table III of the Mrs. Maunder's article. He calculated the projected area of spots from the corrected area of spots of this table without taking into account the dependence of the projected area on the heliographic latitude of spots. It is easy to reproduce from the electronic version of the GPHR the Table III of the Mrs. Maunder's article and to collect the projected area of spots directly. The discrepancy between the projected area of electronic catalogue and the one calculated by Minnaert is large. However, the recent results do not exclude the validity of an improved version of this model.

Surprisingly, in the case of the small spots (<20 MSH) the results derived from DPD and SFC are opposite. The result from DPD could be explained with a small E-W inclination of spots, which could cause an observable effect only for small spots near the limb. The result from SFC seems to be the most difficult to explain at present. The found small E-W asymmetry may be a real effect but it cannot be excluded that it is only an artifact coming from the large

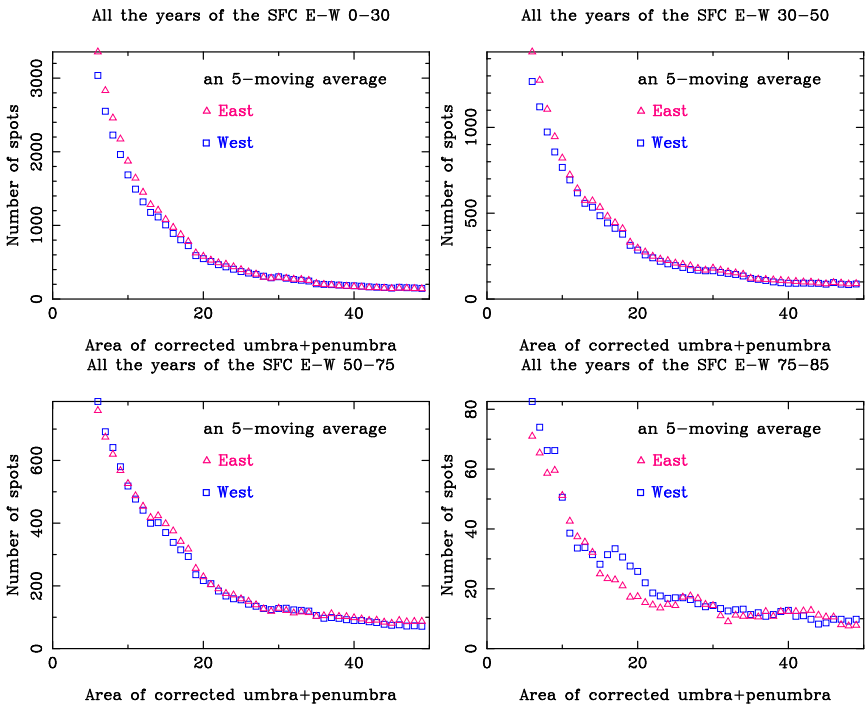

Figure 3: *Distribution of the number of the spots of SFC as a function of the corrected sunspot areas from the central meridian to the limb.*

scale intensity inhomogeneities of MDI continuum images.

On the basis of the present study the existence of East-West asymmetry of the number of small spots (<20 MSH) seems to be a real effect but its flavors cannot be determined exactly yet. If it exists,

this asymmetry is probably a weak effect, which requires further investigations.

Acknowledgement

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