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North-South asymmetry in the solar cycle 23 extracted from the Solar Feature Catalogues

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Abstract. The statistical results in sunspot and plage distributions in 1996-2004 obtained from the Solar Feature Catalogues (SFC) are presented. Sunspot and plage area distributions reveals a strong North-South asymmetry of about 0.4 and the period of about 7 years for sunspots and of 0.6 and period of about 8 years for plages with both asymmetries decreasing towards the next cycle minimum. This North-South asymmetry is also observed in the cumulitative areas of sunspots and plages showing a periodical domination of the Northern and Southern hemispheres from the beginning of the cycle relaxing to zero towards the current solar minimum. The resulting, or excess, magnetic fluxes in 1997-2003 covered by sunspots reveal mostly a positive magnetic flux in the Northern and the negative one in the Southern hemispheres while in 1996 there are signs of the magnetic fluxes in the hemispheres changing to the opposite. These asymmetries reflect some essential properties of the global solar activity to be accounted for in the solar dynamo modelling.

Key words. Sun: magnetic field – Sun: dynamo – Sun: Sunspot areas – Sun: Plage areas– Sun: cumulitative area – Sun: North-South asymmetry

1. Introduction

The recent advances in automated feature detection and verification procedures in comparison with the existing manual methods allowed to create the fully automated Solar Feature Catalogues of sunspots, plages (active regions) and filaments with many extra-parameters extracted which are not available in the manual detections (Zharkova et al. 2005).

New hybrid techniques for automatic identification of sunspots on full disk SOHO/MDI continuum images and plages on full disk Meudon Ca II K3 images obtained in 1996-2004 were introduced using the edge detection (for sunspots) (Zharkov et al. 2005) and region growing (for plages) (Benkhalil et al. 2005). The detected features were verified by magnetic field measurements from the line-of-sight (LOS) magnetograms captured by the SOHO/MDI instrument. The both techniques were used for extraction with high accuracy of the feature sizes, areas, locations, lifetime, contrast, intensities and magnetic fields (Zharkova et al. 2005).

As a component of solar sctive regions, sunspots and their behaviour are used in the modelling of the total solar irradiance during the solar cycle and also in the study of Active Region evolution and in the forecast of solar flare activity (Steinegger et al. 1996). The attempts to predict a solar activity cycle using the

Send offprint requests to: V. Zharkova existing sunspot numbers with the precursor-type or non-linear models (Orfila et al., 2002; Shatten and Hoyt, 1998) or fuzzy logic techniques (Zhou et al., 2002) did not reveal a strong predictive power, possibly, because of a limited number of classifiers used for the prediction that is restricted by the existing sunspot number dataset.

Hence, better identification and characterisation of sunspots and plages is required for a quantitative study of the solar cycle and understanding of the driving force of the solar activity and its forecast.

In this paper the time series from the Solar Feature Catalogues for sunspot and plage areas are investigated in Section 2.1 and for their magnetic field in Section 2.2 with the conclusions drawn in Section 3.

2. North-Sourth asymmetries in the cycle 23

2.1. North-South asymmetry in area distributions

There is a well defined asymmetry in sunspot area and cumulatitative area variations with the areas covered by sunspots being much higher in the Northern hemisphere than in the Southern one. The top graph in Figure 1 shows the sunspot cumulative area versus time and the bottom graph show the area asymmetry for the Northern and Southern hemispheres during the 1996-2004 time period.

From Figure 1 (top) one can see that the increase of activity in 1996-97 starts in increased areas in the Southern hemisphere and only in 1998 is it picked up in the Northern one. Similar to the conclusion by Temmer et al. (2002), towards the cycle maximum in 1998, there is an increase in the activity in the Northern hemisphere was followed in 2000 by a smaller increase in the Southern one, after which the Northern area activity prevails above those in the Southern until 2002, then the Southern hemisphere areas become compatible or higher then those of the Northern one.

In order to quantify the observed asymmetry, the area asymmetry coefficient a_{NS} was calculated for the total sunspot areas in the

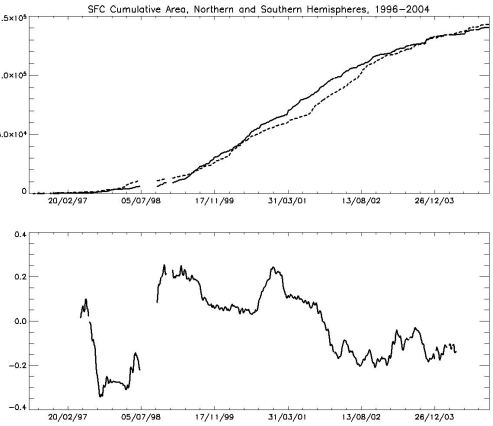

Fig. 1. Top graph: Sunspot cumulative area for Northern and Southern hemishperes, 1996-2004, with the areas plotted in *y*-axis, the time in *x*-axis. Solid line corresponds to Northern hemisphere data, dashed - Southern one. Bottom graph: North-South Asymmetry index, 1996-2004, see the text for details.

Northern (a_N) and Southern (a_S) hemispheres with a filter over the 300 days period centered at the date of observation. The results are presented in Figure 1 (bottom).

At the start of the cycle (1996-97) the Southern hemisphere displays an increased level of the sunspot activity with the asymmetry being negative up to -0.4, then in 1998 it changes to the positive one of about 0.2 with the two peaks in 1999 and 2001 pointing to the Northern hemisphere to prevail lasting for another 3 years. From 2002 the asymmetry becomes negative again fluctuating around -0.2 and approaching 0 meaning that the sunspots in both hemispheres have their areas nearly equally increased.

The similar patterns are shown in the plage total and cumulitative areas presented in Figures 2 and 4. Their total areas have even stronger asymmetry than the sunspot ones approaching magnitudes of 0.6 and oscillating around the magnitude of 0.4 before relaxation to zero. This is more pronounced in the plage accumulitative areas in Figure 4 with the relaxation period of about the whole period of the catalogue, or up to 8 years.

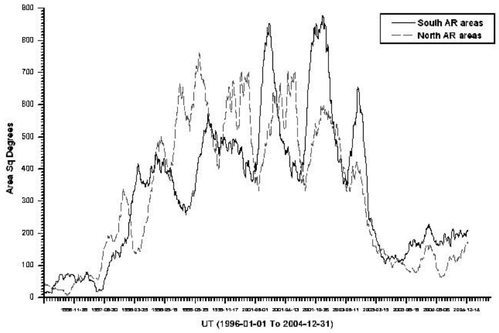

Fig. 2. Plage total areas for Northern and Southern hemishperes, 1996-2004, with the areas plotted in *y*-axis, the time in *x*-axis. Solid line corresponds to the Southern hemisphere data, dashed - the Northern one.

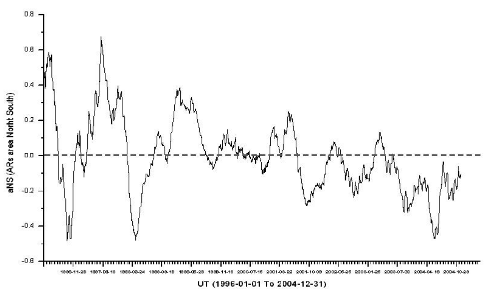

Fig. 3. The North-South asymmetry in the total daily areas of plages.

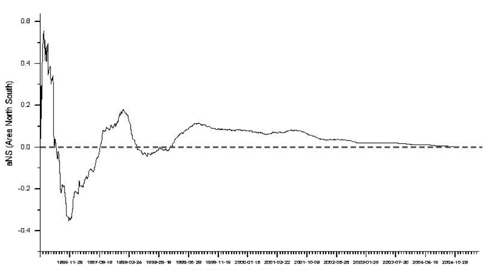

Fig. 4. The North-South asymmetry in the plage total cumulitative areas.

It seems that the asymmetry in sunspot and plage area distributions is much more common than their symmetry that is valid not only around the solar maximum, as it was concluded for the previous cycles (Temmer et al., 2002), but throughout the whole cycle. This asymmetry seems to have a periodical nature with the period of about 8 years that fits surprisingly well the estimations for the dynamo wave recently refined for the turbulent dynamo models by Kryvodubskij (2005).

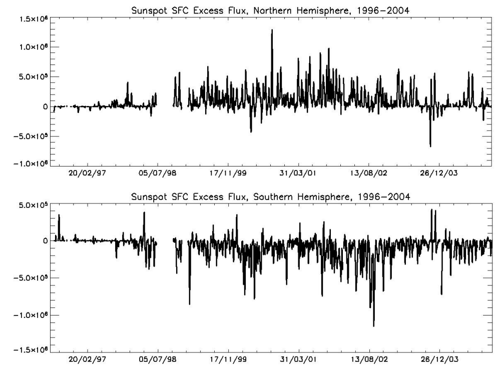

Fig. 5. The excess magnetic field distribution in Gauss plotted for Northern and Southern hemispheres versus the time of observation (1996-2003).

2.2. N-S asymmetry in magnetic field of sunspots

The correspondence of sunspot areas to the locations with high magnetic fields allowed to conclude that the N-S asymmetry for sunspot areas are also valid for their total magnetic fields. There is a minimal umbral magnetic flux of 670-730 G that slightly varies with the solar cycle (Zharkov et al. 2005). Most of the time in 1997-2003 the resulting, or excess, magnetic flux inside sunspots, is positive for Northern hemisphere and negative for the Southern one changing its sign around the solar minima in 1996 and towards 2004 (see Figure 5).

The separation of a magnetic excess flux in the hemispheres, possibly, points out onto the sunspots as concentrations of the leading magnetic polarity field (toroidal filed in the solar dynamo) which is changed during the solar minima. The violation of this separation that coincides with the appearance of trans-equatorial loops can be probes of the deviation of the solar dynamo processes from axisymmetric models.

3. Conclusions

A number of physical and geometrical parameters of sunspot features are extracted and stored in the relational database along with the pixel raster scan of a bounding rectangle. The sunspots detected with both techniques from the two different sources are stored in the database as the Sunspot Feature Catalogue for 8.5 years from May 1996 until December 2004.

At the start of the cycle (1996-97) the Southern hemishpere displays an increased level of the sunspot activity, with the asymmetry up to -0.4 being negative, then it in 1998 it changes to the positive one of about 0.2 with the two peaks in 1999 and 2001 pointing to the Northern hemisphere to prevail in the activity that lasts for another 3 years. In 2002 the asymmetry becomes negative again fluctuating around -0.2 meaning that the sunspots in the Southern hemisphere increase their areas in a decline phase of the solar cycle 23.

The sunspot and plage area distributions prove that the N-S asymmetry is a common reflection of the periodicity of solar activity during the whole cycle not only around its maximum as it was spotted in the previous cycles (Temmer et al., 2002). The detected period of about 7-8 years fits rather well the estimations for the dynamo waves recently refined for the turbulent dynamo model (Kryvodubskij, 2005).

Magnetic field confined by sunspots also shows the signs of the full N-S asymmetry in the resulting, or excess flux. The separation of the magnetic excess flux in the hemispheres supports the idea of sunspots being the concentrations of the leading magnetic polarity field (toroidal field in the solar dynamo) that changes during the solar minima.

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