NORTH–SOUTH ASYMMETRY OF THE POLAR SOLAR WIND AND SOME CHARACTERISTICS OF SOLAR MAGNETIC FIELD

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Abstract. We have found correlated variations of the yearly averaged north–south asymmetry in the polar solar wind speed (Δ_{sol}) and the ratio of the zonal quadrupolar to the zonal dipolar contribution in the inferred coronal magnetic field during the declining phase of sunspot cycle 21. A physically meaningful association between Δ_{sol} and some polar solar magnetic field proxies is also observed during the low sunspot activity periods of the above cycle.

1. Introduction

Three dimensional structure of the solar corona and the associated solar wind flow is basically controlled by the large scale solar magnetic field. The observed north–south asymmetry in the solar coronal structure during sunspot minimum was explained (Oscherovich *et al.*, 1985) using a heliomagnetic model with a zonal quadrupole component in addition to a zonal dipole component.

Generally north–south asymmetry in polar features of the sun viz polar coronal holes, high latitude solar wind, polar faculae etc are associated with the properties of zonal components of the solar magnetic field. In this work we have studied the relation between north–south asymmetry in observed polar solar wind speed (from IPS measurements) and some characteristics of zonal solar magnetic field and its proxies for the sun spot cycle 21.

2. Method of analysis

(i) Solar wind velocity data averaged over solar longitude for heliolatitudes $\pm 60^0$ published by Rickett and Coles (1991) using San Diego IPS observations for the years 1976–1985 is used to calculate the Polar north–south asymmetry in Solar wind velocity defined as

$$\Delta_{sol} = \frac{N - S}{\left(\frac{N+S}{2}\right)} \times 100\%$$

N – Solar wind velocity for $60^0 N$ heliographic latitude

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S – Solar wind velocity for $60^0 S$ heliographic latitude

(ii) Using published spherical harmonic coefficients of the solar magnetic field for cycle 21 by Hoeksema and Scherrer (1986) (Calculated using potential field modelling of photospheric magnetic field observations from WSO, Stanford.) We have estimated the following.

a) Combined contribution of all zonal harmonics $[g_l^m]$ with dipole symmetry $[m = 0, l = 1, 3, 5, 7, 9]$ in the inferred coronal field at $r = 2.5R_\odot$, defined as E_R.

b) Similarly combined contribution of all zonal harmonics with quadrupole symmetry $[m = 0, l = 2, 4, 6, 8]$ defined as O_R.

c) The ratio $\beta = \frac{E_R}{O_R}$ is calculated for each Carrington rotation [CR 1642–CR1770] for the years 1976–1985 in cycle 21. The yearly average of β defined as $\overline{\beta}$ is also calculated for the above years.

(iii) From published K-corona synoptic PB charts of HAO, Hawai the average heliographic latitude of the boundary of the polar coronal holes (Fisher and Sime, 1984) for each carrington rotation for the years 1976–1978 and 1982–1985 is calculated separately for northern hemisphere $(\overline{\theta}_N)$ and southern hemisphere $(\overline{\theta}_S)$. The parameters $\cos\overline{\theta}_N$ and $\cos\overline{\theta}_S$ are proportional to areas of polar coronal holes in the corresponding solar hemisphere. North–South asymmetry in the polar coronal hole area is approximately evaluated by a parameter

$$\overline{\Delta}_c = \frac{N - S}{\left(\frac{N+S}{2}\right)} \times 100\%,$$

$$N = \cos\overline{\theta}_N, \qquad S = \cos\overline{\theta}_S$$

(iv) Using published north–south asymmetry in the maximum heliolatitudinal extension of the heliospheric current sheet (Δ_{HCS}) about heliographic equator [Girish and Nayar, 1990] we have determined the number of solar rotations for each year where the HCS is extended more in Southern heliosphere for the years 1976–1978 and 1981–1985 $(\Delta_{\mathrm{HCS}} < 0)$.

(v) Sheeley's flux tube expansion factor [Wang and Sheeley, 1991] is defined as

$$f = \left(\frac{R_P}{R_C}\right)^2 \left(\frac{B_P}{B_C}\right)$$

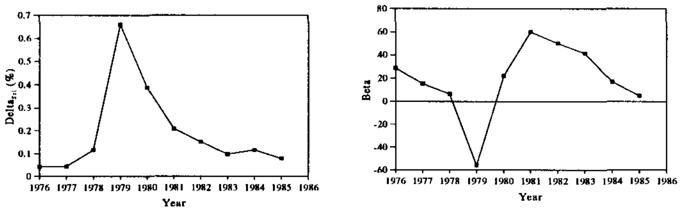
R_P and R_C are photospheric and coronal radial distances. We want to calculate $\overline{f}$ averaged over the solar polar cap (in a particular heliohemisphere) we assume

$$\overline{f} = \left(\frac{R_P}{R_C}\right)^2 \left(\frac{\overline{B}_P}{\overline{B}_C}\right)$$

we use proxies for $\overline{B}_P$ and $\overline{B}_C$ for the polar regions of the sun. For a given heliohemisphere,

$\overline{B}_P \propto$ yearly number of polar faculae, NPF

Fig. 1. Variations of (a) $\overline{\beta}$ and (b) $\Delta_{\rm sol}$ for the years 1976–1985



(b) (a)

$\overline{B}_C \propto \cos\overline{\theta}$ (Proportional to area of polar coronal hole)
We calculate

$$\frac{\overline{f}_N}{\overline{f}_S} = \frac{(NPF)\text{north}}{(NPF)\text{south}} \times \frac{\cos\overline{\theta}_S}{\cos\overline{\theta}_N}$$

for the years 1976–1978, 1982–1985.

Since f is inversely related to solar wind speed we have, when

$$\frac{\overline{f}_N}{\overline{f}_S} < 1 \qquad \Delta_{\rm sol} > 0$$

and $$\frac{\overline{f}_N}{\overline{f}_S} > 1 \qquad \Delta_{\rm sol} < 0$$

we have used published polar faculae counts [Sheeley, 1991] and calculations of $\overline{\theta}_N$ and $\overline{\theta}_S$ discussed in 2(iii) for the above analysis.

In table 1, we have given the percentage of solar rotations where $\Delta_{HCS} < 0$, $\overline{\Delta}_c$, $(\frac{\overline{f}_N}{\overline{f}_S})$, $\Delta_{\rm sol}$ and $\overline{\beta}$ for each year between 1976 to 1985. The symbol X indicates no data and $*$ indicates that the corresponding parameter has a physically meaningful association with $\Delta_{\rm sol}$. In Fig 1 and 2 we give the variation of $\overline{\beta}$ and $\Delta_{\rm sol}$ respectively for years 1976 to 1985.

3. Discussion

From Figure 1 and 2 we find correlated variations of the north–south asymmetry in polar solar wind $|\Delta_{\rm sol}|$ and the ratio of the zonal quadrupolar to zonal dipolar contribution of β in the inferred coronal magnetic field during the declining phase of sunspot cycle 21. This feature is not observed during the rising phase of the above cycle.

A physically meaningful association between north–south asymmetry in polar solar wind and other polar magnetic field proxies will exist under the following conditions.

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TABLE I

Comparison of $N - S$ Asymmetry in Polar Solar Wind and related parameters during cycle 21

Year	% of solar rotations with $\Delta_{\mathrm{HCS}} < 0$	$\bar{\Delta}_c$ %	$\bar{f}_N/\bar{f}_S$	Δ_{sol}	β_{av}
1976	100*	8*	0.65*	28.6	0.042
1977	100*	11*	1.20	15.4	0.044
1978	23	-21	0.95*	6.5	0.116
1979	X	X	X	-56	0.660
1980	X	X	X	+22	0.388
1981	64*	X	X	60	0.208
1982	40	-6.5	1.7	50	0.151
1983	46	-4	2.8	41.5	0.097
1984	69*	49*	0.72*	17	0.116
1985	69*	31*	0.69*	5	0.078

1. The sign of Δ_{sol} must be opposite to that of Δ_{HCS}
2. The sign of $\bar{\Delta}_c$ must be similar to that of Δ_{sol}
3. The sign of Δ_{sol} must be in agreement with the inequalities mentioned in 2(v).

From table 1, we can find that only during low sunspot activity years we can see a meaningful association between Δ_{sol} and other polar solar magnetic field proxies in the cycle 21.

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