THE ORIGIN OF THE 28- TO 29-DAY RECURRENT PATTERNS OF THE SOLAR MAGNETIC FIELD

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Abstract. Numerical simulations of the Sun's mean line-of-sight magnetic field suggest an origin for the 28- to 29-day recurrent patterns of the field and its associated interplanetary phenomena. The patterns are caused by longitudinal fluctuations in the eruption of new magnetic flux, the transport of this flux to mid latitudes by supergranular diffusion and meridional flow, and the slow rotation of the resulting flux distributions at the 28- to 29-day periods characteristic of those latitudes.

1. Introduction

During the past few years, we have developed a program to simulate the evolution of the Sun's photospheric magnetic field (Sheeley et al., 1983, 1985; DeVore et al., 1985). Bipolar magnetic regions are the sources of new photospheric flux, and this flux is transported over the surface by supergranular diffusion, differential rotation, and meridional flow. We determine the influence of the source properties and transport parameters on the field patterns by varying their input values and comparing the resulting simulations with each other and with observations.

One of the initial objectives of our program was to study the origin of the 28- to 29-day recurrent patterns of the solar magnetic field. The patterns were discovered by Svalgaard and Wilcox (1975) from inferred measurements of interplanetary magnetic field polarity during the years 1926–1973. Although such patterns have since been identified in the mean line-of-sight solar magnetic field (Scherrer and Svalgaard, 1977), the solar horizontal dipole field (Hoeksema, 1984), and the distribution of low-latitude coronal holes (Sheeley and Harvey, 1981), their origin has remained obscure (cf. Hundhausen, 1977; Sheeley, 1981). In this paper, we describe mean-field simulations which suggest a plausible explanation for these recurrent patterns.

2. Approach

As in a previous paper (Sheeley et al., 1985), we calculate the daily value of the Sun's mean line-of-sight field as seen from Earth and display the results in Bartels's (1934) format. In this format, vertical patterns indicate long-lived structures that return with 27-day synodic rotational periods, while patterns slanted from upper left to lower right indicate long-lived structures that return with periods greater than 27 days. A Bartels display of the mean magnetic field measured at the John M. Wilcox Solar Observatory

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Fig. 1. Bartels displays of the mean line-of-sight solar magnetic field. Column 1 shows the mean field measured at the John M. Wilcox Solar Observatory. Column 2 shows the mean field simulated with our 'standard model' of source properties and transport parameters. Columns 3–5 show the mean field simulated with the indicated variations on the properties of the sources. Entries shaded light or dark refer to positive- or negative-polarity fields with strengths of 0.1 G or greater, respectively, while neutral shading denotes fields of either polarity with strengths below 0.1 G. Very dark entries indicate missing data.

is shown in column 1 of Figure 1. Slanted patterns occur not only during the rising phase of sunspot cycle 21 (1977–1978) and through sunspot maximum (1980), but also during the declining phase (1981–1983). As we shall see, the simulations suggest that these patterns originate in slowly rotating, mid-latitude distributions of photospheric flux.

3. Results

We begin by establishing a reference calculation, our 'standard model', for comparison with the observations and with other simulations (cf. Sheeley et al., 1985). The transport parameters include a diffusion constant of 400 km$^2$ s$^{-1}$, the solar rotation formula determined by Snodgrass (1983), and no meridional flow. We use the National Solar Observatory synoptic magnetogram for Carrington rotation 1646 as the initial flux distribution, and we use estimates of the fluxes and coordinates of nearly 2500 bipolar magnetic regions which erupted during 1976–1984 as the sources of new flux. The resulting mean field is shown in column 2 of Figure 1. Although there certainly are