DYNAMICS OF ACTIVE LONGITUDES AS INFERRED FROM SUNSPOT OBSERVATIONS

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ABSTRACT

The data from the Greenwich Observatory for 1879-2002 (cycles 12-23) have been used to plot a time (years) vs. Carrington longitude diagram of distribution of the rotation-summed sunspot areas. Then, the active longitudes have been identified on these diagrams by intensive long-lived features (sunspot formation zones). The behaviour of the active longitudes (their location, shift, and intensity variations) has been analysed over the entire time interval under consideration.

1. INTRODUCTION

It is well known that the most vigorous manifestations of solar activity (major centres of activity, large sunspot groups and complexes, and proton flares) are confined to a narrow band of heliolongitudes, referred to as active longitudes (AL). These features have been investigated by various authors, in particular [1-13]. In this work, an attempt is made to analyse their behaviour over a long time interval (1879-2002) using the Greenwich data on sunspot areas.

2. DATA PROCESSING

As an input parameter for our study, we have taken the daily areas of each sunspot group recorded at the Greenwich Observatory during 1879-2002 (cycles 12-23) summed up over a Carrington rotation (henceforth referred to as rotation-summed sunspot areas). This parameter is chosen, because it outlines the regions of intensive sunspot activity (active longitudes) much better than the rotation maximum sunspot areas or relative numbers of sunspot groups. Besides, unlike these, the rotation-summed sunspot areas change in a broad range (from 0 to 25000 millionths of visible hemisphere (m.v.h.) depending on the group intensity. Therefore, their distribution on the time-longitude diagram reveals most clearly the major sunspot formation centres, while the randomly distributed small sunspots with the rotation-summed areas less than 2000 m.v.h. form but a weak background, which does not prevent the active longitudes from being isolated.

Fig. 1 illustrates the time-longitude diagrams of the rotation-summed sunspot areas for 1879-2002. Only the summed areas more than 2000 m.v.h. have been used. For convenience of consideration, the time scale is in years instead of Carrington rotations. The grid of the rotation-summed sunspot areas versus heliolongitude and time was obtained with a resolution of 1 Carrington rotation and 1° of Carrington longitude. The resulting diagrams represent quite exactly the distribution of the major sunspot formation zones. The zones with S>10000 m.v.h. have a length scale of ~30° in longitude and a lifetime from ~1.5-2 to 5-6 years. One can note that the distribution of many sunspot formation zones changes every 1.5-2 years almost simultaneously at all heliolongitudes. However, each zone stays at one and the same Carrington longitude all over its lifetime (from 1.5-2 to 6 years).

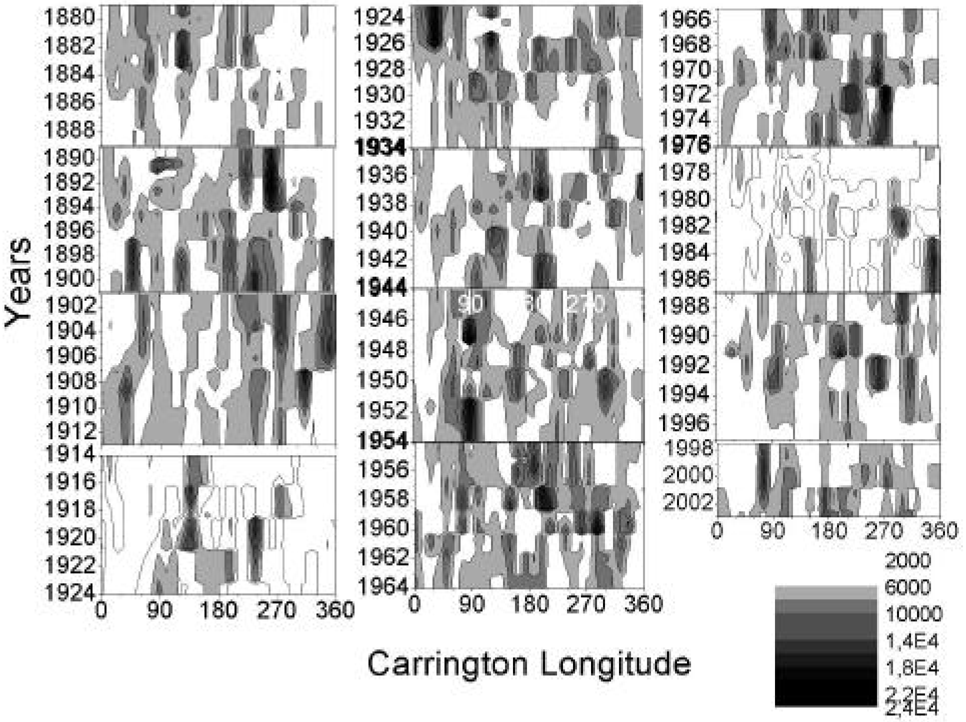

Fig. 1. Time-longitude diagrams of the rotation-summed sunspot areas for 1879-2002.

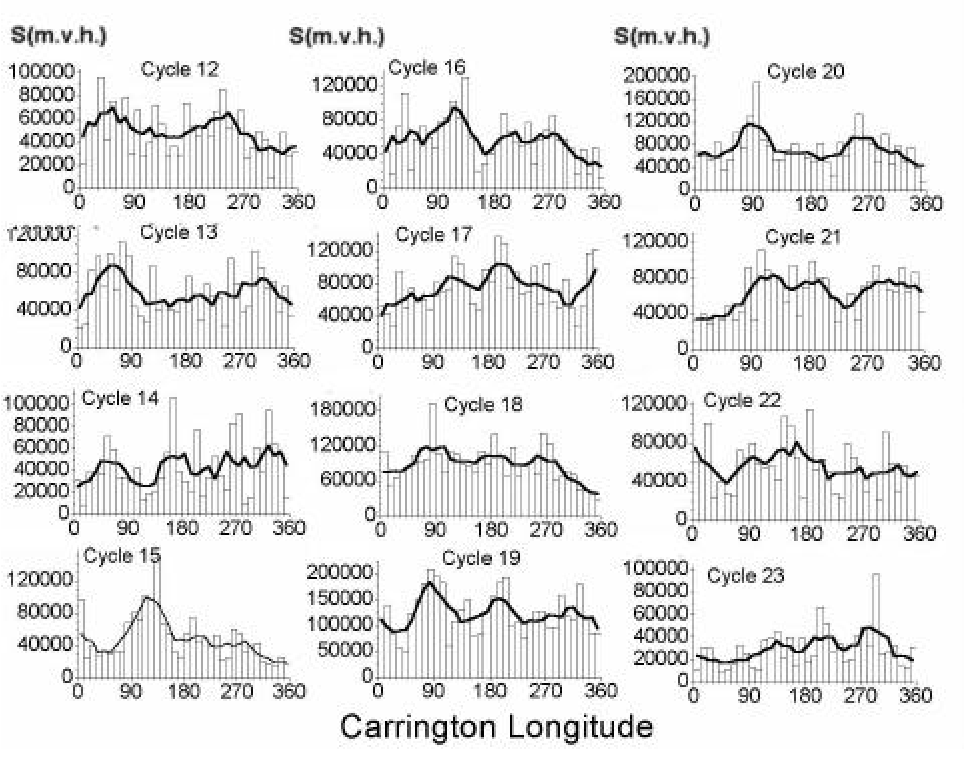

Fig. 2. Histograms of longitudinal distribution of the total sunspot areas over a cycle for cycles 12-23.

3. DYNAMICS OF ACTIVE LONGITUDES

In order to isolate the active longitudes, we have plotted the longitudinal distribution of the rotation-summed sunspot areas summed over each cycle for solar cycles 12-23 (Fig. 2). The histograms are plotted at 10° steps. The same histograms represent the smoothed curves obtained by averaging over moving intervals equal to 5 rotations. The curves show that two active longitudes separated by an interval of ~180° are usually observed, though occasionally an additional third maximum (3rd AL) arises between them. The longitudinal position of AL changes from cycle to cycle. The change is sometimes significant and abrupt, and sometimes it is virtually absent. The AL at ~90° is most stable. It can be traced over nearly 7 cycles from cycle 15 to 21. Another rather stable active longitude at ~270° is observed in cycles 16, 18, 20, 21, and, apparently, 23. From cycle 15 to cycle 22, an active longitude exists at the heliolongitudes of ~180°-210°, being enhanced in cycles 16-19 and 21-22. The AL at ~ 0° is observed in cycles 14-15, 17, and 21-22. Thus, four active longitudes have been revealed in different cycles: at ~90°, ~270°, ~180°, and ~0°. In some cycles, three of them exist simultaneously, and sometimes, though rarely enough, all four AL may be present. The results of our study agree fairly well with the results obtained by other authors [2-4, 6-10, 12, 13], differing only in some minor details.

4. TIME VARIATION OF THE INTENSIVE SUNSPOT FORMATION ZONES

In accordance with the four AL mentioned above, we have isolated four sectors of the Carrington heliolongitudes: 50°-130°, 130°-230°, 230°-330°, and 330°-50° in the following rotation. Then, all rotation-summed sunspot areas have been summed in every sector, and time variations of the obtained values have been plotted for the entire time interval under consideration (1879-2002). Figure 3 illustrates such variation in the sector of 50°-130° for 1965–2002. Besides the 11-year variation, the curve clearly reveals quasi-annual and quasi-biennial variations. In order to analyze in more detail the frequency spectrum of the obtained total sunspot areas in each of the four sectors for the interval from 1914 to 2002 (cycles 15-23), we have plotted the Fourier spectra in the range of periods from ~0.4 to 25 years. An example of such spectrum for the heliolongitudinal sector of 50°-130° is represented in Figs. 4 and 5. The highest maximum in the spectrum proved to correspond to the periods of ~5-6 years, rather than 11 years. In the range of periods from 0.4 to 3 years (Fig. 5), the best pronounced spectral maxima correspond to the periods of 0.5, 0.9-1.0, 1.2, 1.6 and 2 years well known in the solar physics. The solid line in Figs. 4 and 5 corresponds to the time interval from 1914 to 2002, and the dashed line, to the interval from 1965 to 2202. The periods of 0.9-1.0, 1.2, 1.6 and 2 years are, obviously due to quasi-annual and quasi-biennial oscillations of the large-scale magnetic field. The origin of these oscillations still remains a puzzle. Nevertheless, their close relationship with active longitudes (or, to be more exact, with temporal characteristics of the intensive sunspot formation zones) may be regarded as proven.

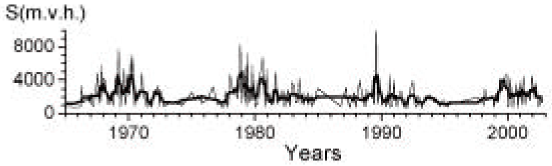

Fig. 3. Variations of the rotation-summed sunspot areas for the heliolongitudinal sector of 50°-130°.

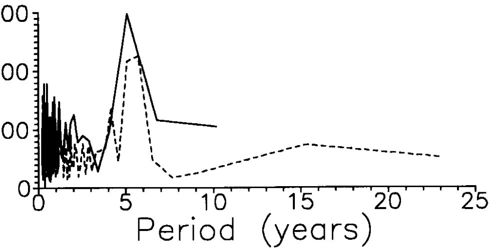

Fig. 4. Fourier spectrum of the rotation-summed sunspot areas in the range of periods from ~0.4 to 25 years for the heliolongitudinal sector of 50°-130°.

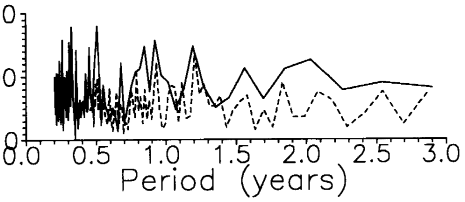

Fig. 5. Fourier spectrum of the rotation-summed sunspot areas in the range of periods from ~0.4 to 3 years for the heliolongitudinal sector of 50°-130°.

5. CONCLUSION

1. The active longitudes are a manifestation of the intensive sunspot formation zones with a rotation-summed sunspot area S>10000 m.v.h., a length scale in longitude of about 30°, and a lifetime from about 1.5-2 to 5-6 years. Each zone stays at one and the same

Carrington longitude all over its lifetime (from 1.5-2 to 6 years).

2. Smoothing of the intensive sunspot formation zones over heliolongitude and summing over a cycle enables identification of active longitudes. Four active longitudes are mainly observed at ~90°, ~270°, ~180°, and ~0°. The active longitudes usually appear in pairs (90° and 270° or 180° and 0°) and are spaced by ~180° within a pair. In some cycles, one can observe three or even all four AL existing simultaneously, though the latter is very rare.

3. The longitudinal distribution of the intensive sunspot formation zones changes almost simultaneously at all heliolongitudes every 1.5-2 years, which is, apparently, a manifestation of quasi-biennial oscillations of the large-scale solar magnetic fields. The same conclusion can be drawn from the spectral analysis of the time series of total sunspot areas in the heliolongitudinal sectors corresponding to the isolated active longitudes. In the spectra under investigation, the highest maximum corresponds to the period of ~5-6 years. In the range of periods from 0.4 to 3 years, the best pronounced spectral maxima correspond to the periods of 0.5, 0.9-1.0, 1.2, 1.6 and 2 years, well known in solar physics.

Acknowledgments. This work is partially supported by the Russian Foundation for Basic Research (grant no. 01-02-16307) and INTAS Project no. 2000-840.

6. REFERENCES

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