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Distribution of Sunspots in Longitude

A. S. RAMANATHAN AND R. JAYANTHAN

Abstract·—A study of the distribution of sunspot activity in longitude has been made for six solar cycles covering the period 1889 — 1954. Correction for differential rotation for individual groups has been made The study has revealed that (a) spot activity integrated over a complete cycle shows meridional structure (b) the centres of spot activity show occasionally migration in longitude; but this migration is neither regular nor always in the same direction.

Introduction

Attempts in the past to study the distribution of sunspots in longitude were mainly directed towards finding oue some law of periodicity analogous to the well known relations representing changes in the latitudes of spots during tht eleven year cycles. The most comprehensive of these was that of Losh (1938) who has also given a good summary of earlier work in the field. Basing her work on the data in the Greenwich photoheliographic results for the years 1916—1934, Losh concluded that there are strong indications of regions of maximum and minimum solar activity inferred from a study of both the Wolf numbers grouped according to synodic solar rotations and the distribution of sunspots in heliographic longitude. She also noticed that the regions of maximum and minimum activity do not necessarily appear in the same longitudes in the northern and southern hemispheres but show a strong tendency to appear in regions approximately 180° apart perhaps at the opposite extremities of a diameter of the sun.

Methods and Results

The present investigation was undertaken with a view to check the rather inconclusive results of Losh. Also the study has been extended to cover a longer period (1889—1954) The precision of the analysis has been improved by applying corrections to the observed longitudes of every individual spot group taking into account differential rotation of the sun. The apparent drift in longitude that any spot group will show was calculated from Carrington's formula $\xi = 14°.37 - 2°.60 \sin^2\phi$ where ϕ is the latitude and ξ the angular velocity of the surface layer (in degrees per day).

Drift corrections applied to the observed longitudes of spot groups (based on a constant solar rotation period of 25 38 days) yield longitudes referred to solar rotation 780 beginning on January 13·42, 1912. This would mean that the corrected values of the longitudes would be with reference to the commencement of rotation 780, for a rigid sun.

The corrected longitudes and the mean areas of sunspot groups (corrected for foreshortening) were tabulated for all the years under study for the eight latitude belts 0—10°, 10—20°, 20—30° and greater than 30° north and south in 36 longitude zones of 10° each. Graphs were drawn between the longitude and the total spot area for each year for the eight latitude zones separately and then combining all latitudes for each hemisphere separately. Graphs were also drawn between longitude and total area for complete eleven year cycles for latitude intervals (0—20°) and (0—90°) north and south.

The curves showing the distribution in longitude of spot activity for each year separately did not reveal any striking regularity. No zone of maximum activity was found to be common to all year, nor was there a prominent progressive change in the longitudinal zones showing maximum activity. However some of the curves drawn for latitude interval 0—90° for each hemisphere showed the zone of maximum activity around 0° (or 360°) in the earlier part of the cycle and near 180° towards the end, there being some suggestion of a migration of the zone of maximum activity towards middle longitudes as the cycle progressed.

The curves representing distribution in longitude of spot activity for complete eleven year cycles showed some striking regularities. There was very close similarity between the curves for latitude interval (0—20°) and for the latitude interval (0—90°) for any cycle in either hemisphere. Of course this is partly due to the fact that the maior part of the spot activity in a cycle is confined to the latitude belt (0—20°). Also the curves for the northern and southern hemispheres for any cycle resembled each other. This similarity was found to be very close in the cycle commencing in 1923. This would mean that there is no reason to believe that the distribution in longitude of sunspot activity in the northern hemisphere is different from the southern as has been found by earlier workers in this field Figure 1 (a-f) represents the distribution of sunspot activity in longitude for complete eleven year cycles for the latitude interval (0—90°) for the northern and southern hemispheres.

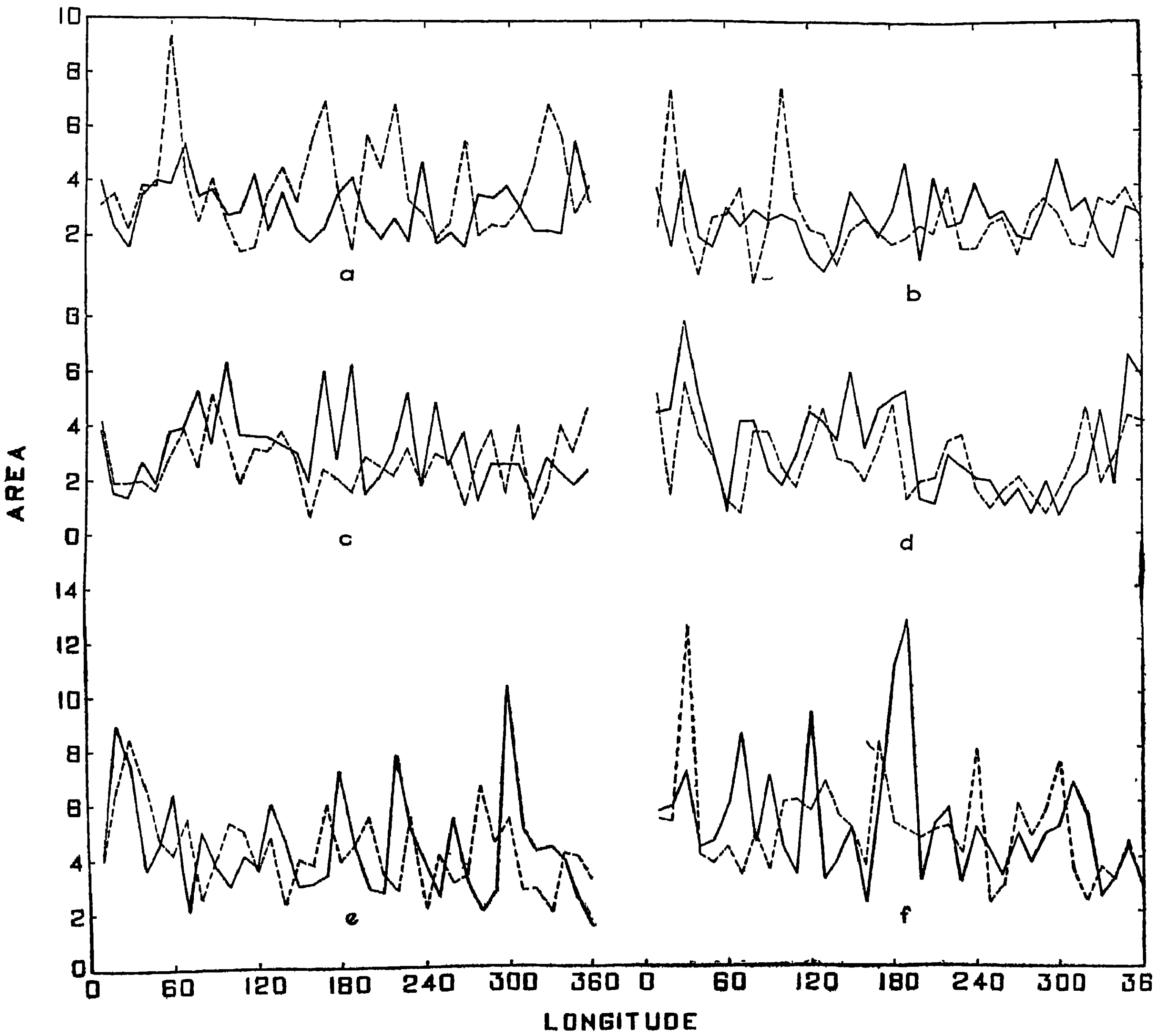

FIGURE 1 /a-f :—Total spot area plotted against heliographic longitude for all latitudes (0-90°) for the six eleven year cycles commencing from 1889 and ending in 1954.

The above facts lead to the conclusion that spot activity integrated over a complete cycle shows meridional structure.

In order to examine more carefully the migration in longitude of centres of strong spot activity, graphs were drawn representing the principal centres of spot activity in longitude for each year for the entire latitude interval (0—90°) for each hemisphere separately. It was not difficult to identify the principal centres, as distinct longitudinal zones showed activity far more than other zones. When the principal centres of activity extended to two or three adjacent zones the weighted centre of the activity was found and the zone in which this centre lay was taken to be the active zone. Figure 2 represents the distribution in longitude of the principal centres of spot activity in the northern and southern hemisphere respectively. From the figure one can see that there is a tendency for migration in longitude of the centres of activity with time on some occasions. In such cases the migration is regular and conspicuous whereas at other times the migration, if at all, there is neither uniform nor in the same direction Whereas the migration of active sunspot zones is quite apparent in the first four cycles (1889—1934) their distribution in longitude remains practically the same in the last two cycles (1934—1954) and the migration is quite inconspicuous Thus it would appear that neither are there distinct zones of spot activity fixed on the hypothetical rigid sun for all the time nor is there evidence to show that there is *always* a *regular* migration in longitude of the centres of activity with the advance of time

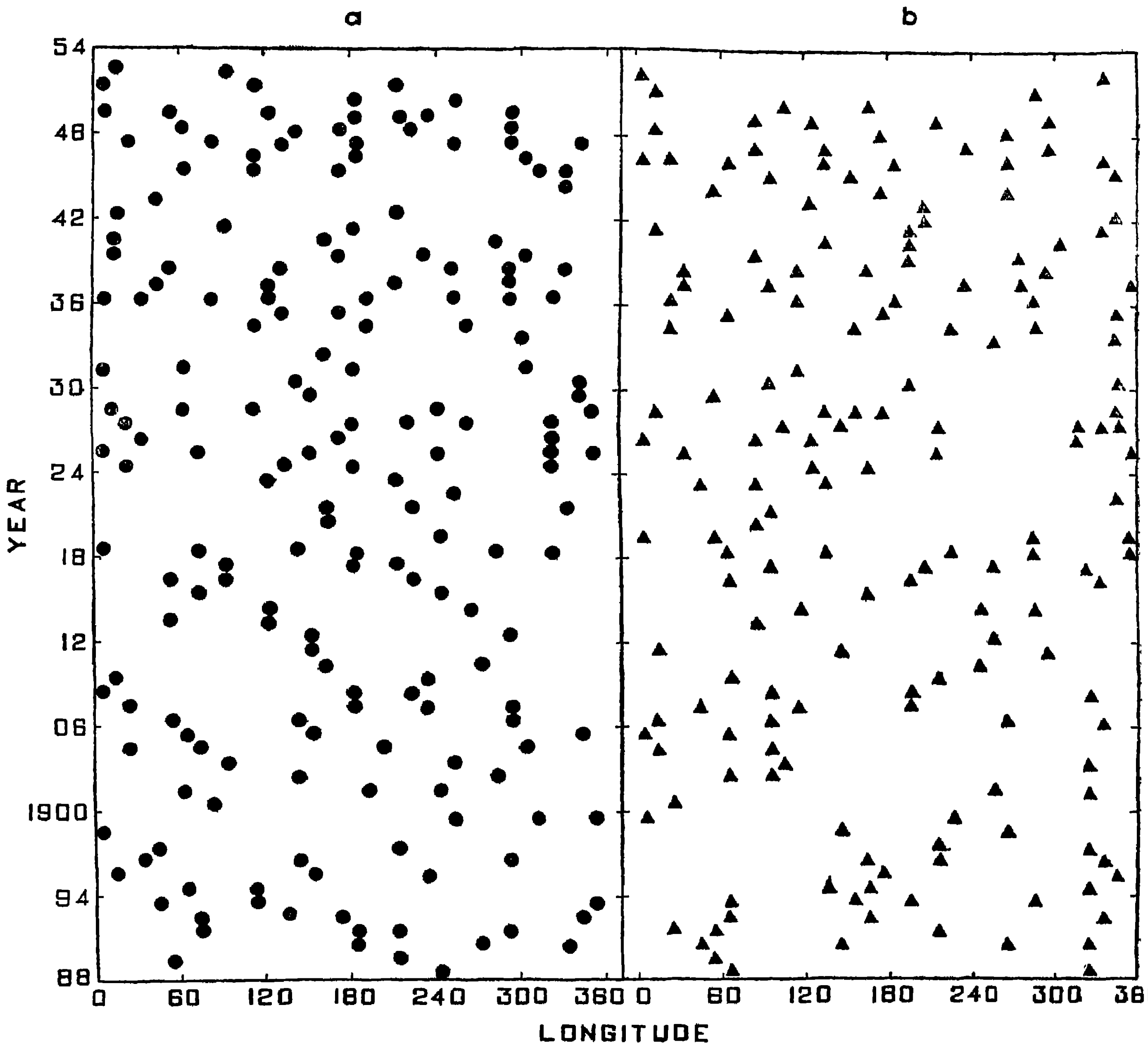

FIGURE 2 (a&b) —Distribution of principal centres of sunspot activity in longitude for the period 1889 to 1954 for northern hemisphere (●) and southern hemisphere (▲) respectively

If we proceed on the assumption that there are fixed centres of activity on a rigid sphere in the interior and that the layers above have the angular velocities observed on the surface, the reduction of the observed positions of spot groups to a single system of coordinates fixed on the hypothetically rigid sun as we have done should give a constant distribution of spot activity independent of time Since this is not the case and since spots are not likely to be caused by agencies above the photosphere we are led to conclude that the centres of activity on the sun are not confined to any distinct longitudinal zones.

A statistical analysis of the results also revealed that the distribution of spot activity in longitude during the six cycles analysed, is random. For convenience the whole surface was divided into six longitude zones each of 60° and the calculated coefficient of association between the various sunspot cycles and the occurrence of spot activity in particular zones yielded the low value of 0·14.

The relation between the random drift of the centres of activity with the probable slow torsional oscillations of the equatorial belt of the sun is not easy to decide. We believe, however, that a detailed study of the drift in longitude of localised regions of magnetic field observed over a considerable period may throw some light on the problem.

We wish to record here the valuable discussions we had on the problem with late Dr. A. K. Das, former Deputy Director General of this observatory. Our thanks are also due to Dr. M. K. Vainu Bappu, Director of this Observatory, who kindly went through the paper and offered valuable suggestions.

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A. S. Ramanathan
R. Jayanthan.

Reference

Losh, H.M. **1938, Pub. Obs. U. Michigan 7, 79.**