SUNSPOT MOTION STATISTICS FOR 1965–67
(Research Note)

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1. The Data

We present here sunspot motion statistics for the years 1965-67, based on Sacramento Peak Observatory data. These data are routinely available in the Geophysics and Space Data Bulletin of the Air Force Cambridge Research Laboratories. Our study complements the electron-corona differential rotation measurements for 1964-67 by Hansen et al. (1969), and also recent spectroscopic measurements by Livingston (1969).

The data were screened to exclude spot areas greater than $2000 \times 10^{-6}$ of the disk and total spot areas that were listed as less than the umbral areas for the same spots. Also, spot displacements of greater than 3°/day longitude (relative to the Carrington rotation) and 2°/day latitude were rejected, as were spots within 10% of the limb where position and area errors are largest. These latter criteria are the same as used by Ward (1964, 1965, 1966) in his much more extensive study with Greenwich Observatory data of previous sunspot cycles. In sum, the above restrictions ruled out about 24% of the data.

Since our data sample is relatively small, we will present only the three-year averages of the northern and southern hemispheres taken together. Data for days with more than one observation were averaged. Table I contains the number of observations, after averaging, distributed in 5° latitude belts for the period.

<table>
<thead>
<tr>
<th>Latitude (°)</th>
<th>Number of observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–5</td>
<td>21</td>
</tr>
<tr>
<td>5–10</td>
<td>97</td>
</tr>
<tr>
<td>10–15</td>
<td>323</td>
</tr>
<tr>
<td>15–20</td>
<td>552</td>
</tr>
<tr>
<td>20–25</td>
<td>751</td>
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<tr>
<td>25–30</td>
<td>325</td>
</tr>
<tr>
<td>&gt;30</td>
<td>128</td>
</tr>
<tr>
<td>total</td>
<td>2197</td>
</tr>
</tbody>
</table>

2. Spot Motion Statistics

It is, of course, not known just how well sunspots track the flow in which they reside. Therefore, all spot motion statistics, including the mean longitudinal motion, or differential rotation, must be viewed with some caution when relating them to solar gas motions (see Ward, 1966).

In Figures 1–3, we present the mean longitude and latitude motions and their correlation (all error bars are 5% confidence limits, with each observation treated as inde-

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independent). In Figure 1, we see that the motion in longitude conforms fairly well to the familiar differential rotation profile (solid line, shown measured relative to the Carrington rotation of 14.184°/day with 5% confidence limits) except for the low rotation in the 5–10° belt. The dashed line represents Ward’s (1966) result for the years 1905–1954. We note that the differential rotation at every latitude is higher in the current sunspot cycle, typically by almost 0.1°/day. These rotation rates are also slightly faster than the coronal rates reported by Hansen, Hansen and Loomis (1969).

Part of our high rotation rate is probably due to a different distribution of spot sizes during the first of the current sunspot cycle from the distribution Ward has for the years 1905–1954. That is, 60% of the Sac Peak observations are for spots or spot groups with areas less than $100 \times 10^{-6}$ of the solar disk, as against only 48% in Ward’s sample from Greenwich data. Since it is now well established (Ward, 1966) that the small spots rotate faster (our calculations also show this; see Section 3), we should expect a higher rotation rate with our sample. However, it does not appear that we can explain very much of the difference this way, since having a 20% greater fraction of small spots should increase the overall rotation rate by about 20% of the difference between the small and large spot rates, i.e., an increase of only 0.01 or 0.02°/day compared to the observed increase of almost 0.1°/day.

In Figure 2 are plotted the mean latitudinal motions (solid lines). Most values are
not significant at the 5% level, but there is indication of equatorward motion at low latitudes. This is similar to that found by Tuominen (1955). We note, however, that Ward’s results (unpublished) for the years 1905–1954 (dashed curve) show much smaller values. Only the equatorward motion in the 0–5° belt is significant in his larger sample.

Ward (1964, 1965) has interpreted the correlation between longitude and latitude motions as indicating a horizontal Reynolds stress in the gas flow that transports momentum toward the equator to sustain the differential rotation. Our significant results for this correlation, shown in Figure 3 (solid lines), agree rather closely with those of Ward (unpublished) for the 1905–1954 period (dashed lines).

3. Motion-Area Correlations

Ward (1966) established that at virtually every latitude in the spot zones, the bigger spots rotate more slowly. In our much smaller sample we also see some evidence of this. In Figure 4, we have plotted the differential rotation rate for the spots broken into two groups. The dashed line represents the movement of spots of area greater than $100 \times 10^{-6}$ of the disk (871 observations) and the solid line that of the smaller spots (1326 observations). We see that in the latitude range 10–30°, where 90% of the
data is concentrated, the smaller spots move faster on the average by almost 0.1°/day. This is perhaps twice as large as Ward (1966) found. The average rotation for all zones is 14.30°/day for the small spots, and 14.26°/day for the large ones. The difference of 0.04°/day is essentially the same as found by Ward. Both of our mean rotation rates are lower than Ward’s by about 0.05°/day, which is presumably because our data are only for the first part of a solar cycle, when spots occur preferentially at higher latitudes.

As another indication that the larger spots move more slowly, Ward (unpublished) has found a small but significant negative correlation between the daily longitudinal displacement and spot area, for every five-degree latitude belt between 5 and 30° (the other latitudes did not give significant results). His correlation for all latitudes taken together was about $-0.04 \pm 0.01$, and for the latitudes 15–25°, $-0.05 \pm 0.015$. For the latter latitude range, we also find a negative correlation of $-0.06 \pm 0.05$.

In conclusion, our statistics agree for the most part with those of Ward except that we find some evidence of a faster-than-average differential rotation in the first part of the current cycle.

Acknowledgements

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References