The height of the 9 cm solar emission

(Research Note)

M. Waldmeier
Swiss Federal Observatory, Zürich, Switzerland

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Abstract. The large values of the heights, their dependence on latitude and time as found by Graf and Bracewell can satisfactorily be explained by assuming a constant height of around 18 000 km and by taking into account that the microwave sources do not lay above the spots but above the plages.

For the height of the emission of the 9 cm radiation one finds in the literature values between 15 000 and 28 000 km above the photosphere (Graf and Bracewell, 1972). The uncertainty of the individual results is so large that they do not exclude each other. In the present note we accept a height of 18 000 km.

The first results on the height of the 9 cm emission came mainly from the apparent motion of the radio sources in longitude. To obtain the height with a precision as good as or better than has been achieved from the studies based on the rate of motion in longitude, Graf and Bracewell (1972) have used the latitude displacement between the microwave source and the associated optical feature. In a second paper (Graf and Bracewell, 1973) the authors have used the same method to investigate in more details the time and latitude-variations of the height. Their results differ largely from the earlier ones in three respects: (1) the heights are ranging from 20 000 to 170 000 km, therefore exceeding strongly our accepted value; (2) the height depends on the heliographic latitude; and (3) it depends on the phase of the sunspot-cycle.

The latitude displacement has been measured on the central meridian between the center of the radio source and the corresponding sunspot. From this displacement the heights were obtained under the assumption that the emission region lies vertically above the sunspot. Obviously this is not the case. The 9 cm radiation is mainly a coronal emission. Optical observations of the line 530.3 nm carried out at a height of about 20 000 km show that the coronal condensation responsible for the microwave emission is centered rather to the underlying plage than to the spots. The heliographic latitude of the plages is larger than that of the spots, roughly speaking by about 1°. Taking this into account it is easy to explain the surprisingly large height found by Graf and Bracewell (1973).

In Figure 1 s and f are the centers of the spot group and the faculae surrounding it and $b_s$ and $b_f$ their heliographic latitude. The figure gives the directions in which we see the Sun's center, the spot, the faculae, and the microwave source. The inclination of the Sun's axis toward the ecliptic is neglected. Two different heights, $h_s$ and $h_f$, are obtained depending on whether the source is centered above the spot.
Fig. 1. The heights $h_s$ and $h_f$ deduced from the latitude displacement of the microwave source.

or above the faculae. It follows from Figure 1 that the height $h_s$ calculated by Graf
and Bracewell comes out larger than the 'true' height $h_f$, for which we have
assumed 18 000 km. This is the explanation for the anomaly mentioned under (1).

From Figure 1, taking the Sun's radius as unity, it follows:

$$1 + h_s = \frac{\sin b_f}{\sin b_s} (1 + h_f),$$

or in km,

$$h_s = 718 000 \frac{\sin b_f}{\sin b_s} - 700 000.$$

For the year 1968 Graf and Bracewell have calculated the height $H$ for different
latitudes (Table I). The difference in latitude $\Delta b = b_f - b_s$ between faculae and spots
for the years under consideration are published by Waldmeier (1969–1972). The
calculated $h_s$-values, using $\Delta b = 1.5$ and 1.0° respectively are given in Table I. The
values agree reasonably good with that given by Graf and Bracewell. The decrease
of the apparent height $H$ with increasing latitude is well represented.

<table>
<thead>
<tr>
<th>Latitude</th>
<th>$H$</th>
<th>$h_s(\Delta b = 1.5^\circ)$</th>
<th>$h_s(\Delta b = 1.0^\circ)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>9°</td>
<td>170 000</td>
<td>155 000</td>
<td>106 000</td>
</tr>
<tr>
<td>12°</td>
<td>80 000</td>
<td>121 000</td>
<td>82 000</td>
</tr>
<tr>
<td>15°</td>
<td>60 000</td>
<td>98 000</td>
<td>68 000</td>
</tr>
<tr>
<td>18°</td>
<td>50 000</td>
<td>81 000</td>
<td>60 000</td>
</tr>
</tbody>
</table>

The time dependence of $H$ according to Graf and Bracewell is rather strong
(Table II). This is not an effect of the Sun's activity. In the years 1968–1970 the
sunspot relative number $R$ was practically constant, whereas $H$ dropped from