CENTER LIMB OBSERVATIONS OF INHOMOGENEITIES IN THE SOLAR ATMOSPHERE

II: The Na D and Na 5688 Doublets and the Mg I 4571 Line

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Abstract. Center-limb observations of line-center intensity fluctuations in the Na D and Na 5688 doublets and the Mg I 4571 line are described. For small scale structures the rms distributions for the photospheric lines show maxima of 20% at a heliocentric angle of 40° (Mg I 4571) and 9% at 20° (Na 5688). The rms values for Na D range between 10 and 13% but show no significant maximum. Values for large scale structures are somewhat less.

Auto-correlation curves show a range of structures from 4000 km to 30000 km. Brightness-velocity cross-correlation curves and the actual brightness and velocity tracings from a region near disk-center are also studied. A new method of classifying cross-correlation coefficients calculated over many different ranges within the sample enables one to distinguish the existence and extent of regions of significant cross-correlation within the sample and this is applied both to the results for the Na D lines and for the Mg b lines given in Paper I. It is found that regions of significant correlation may extend for lengths of order 25000 km after which the correlation may abruptly change sign or become negligible. The suggestion made in Paper I that these abrupt changes may occur at the supergranule boundaries is further supported.

The relation between these small scale structures and the 5 min oscillations is investigated.

The question of the reproducibility of these statistical data from day to day and at different positions of the Sun at the same heliocentric angle is discussed and the need for further independent observations is stressed.

1. Introduction

The main purpose of this series of observations is to obtain center-limb line-center rms fluctuation data suitable for use in an analysis of chromospheric structure using methods proposed by Cannon (1970).

In Paper I (Cannon and Wilson, 1970) we reported high resolution center-limb observations of brightness and velocity fluctuations in the Mg b lines. Relative rms intensity fluctuations were obtained as a function of heliocentric angle θ for small, medium and large scale structures. It was pointed out that, because local variations in the rms values are found to occur, the θ dependence of the rms fluctuations must be treated with reserve until further independent data provide a reasonable statistical sample for each line.

The significance of the various structures was investigated using power spectra, auto-correlation and cross-correlation analyses. Further insight was gained by a careful examination of tracings of the actual brightness and velocity fluctuations from the same region near the disk-center. The brightness and velocity cross-correlations of the large scale structures indicated that these structures are associated with the supergranule cells. However, the properties of the small and medium scale fluctuations were
found to be more complex. Some variations between different lines of the triplet could be explained in terms of the different heights of formation of the lines. However, differences were also noted in a given line between two different disk regions at the same heliocentric angle.

In the small scale structures (3000 km–8000 km) a strong negative correlation (i.e. bright features correlate with downward motions) could be followed for a distance of about 25000 km. Abruptly the correlation might become positive for a similar distance or might disappear altogether. Similar variations from region to region were detected by the auto- and cross-correlation analyses for the medium scale fluctuations. It was suggested that the abrupt discontinuities in the cross-correlations of the small scale structures might also be related in some way to the supergranule motions.

In this paper we describe similar studies of the Sodium D and Sodium 5688 doublets and the Mg $\text{I}$ 4571 intercombination line. The D lines are chromospheric lines, formed at approximately the same height in the atmosphere as the b lines while the other lines originate in the upper photosphere.

2. Observations and Method of Analysis

The observations were obtained at the Sacramento Peak Observatory, New Mexico in 1967 and 1968 using the 16" coronagraph coupled with the high dispersion Littrow spectrograph. Table I lists the particular details of these observations. Three scans of

<table>
<thead>
<tr>
<th>TABLE I</th>
</tr>
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<tbody>
<tr>
<td>Details of observations</td>
</tr>
<tr>
<td>Na D</td>
</tr>
<tr>
<td>---</td>
</tr>
<tr>
<td>Date</td>
</tr>
<tr>
<td>Film</td>
</tr>
<tr>
<td>Exposure time</td>
</tr>
<tr>
<td>Slit width</td>
</tr>
</tbody>
</table>

the spectrographic slit were required to cover the disk from center to limb and are defined by

Region I \[ 1.00 > \cos \theta > 0.94 \]
Region II \[ 0.94 > \cos \theta > 0.74 \]
Region III \[ 0.74 > \cos \theta > 0.37 \]

where $\theta$ is the heliocentric angle. The seeing conditions during these observations were good but not quite as good as those obtained during the Mg b observations described in Paper I.
The reduction of the observations followed the procedure outlined in Paper I. The digitising was performed at the High Altitude Observatory in Boulder, Colorado using the same slit opening (40 $\mu m \times 40 \mu m$ – corresponding to about 126 km $\times$ 126 km at disk center) and rate of scan (one point digitised per 36 $\mu m$) as before. True line center brightness fluctuations were obtained from all frames, while doppler shift fluctuations of a lower accuracy were obtained from the Na spectrograms.

Figure 1 shows enlarged positive prints of the D$_1$ and D$_2$ spectra from a section of region I. Also shown are tracings of the velocity and intensity fluctuations derived in the manner described above from these spectra. The scale of the enlargement is approximately the same as the tracings and certain brightness and velocity features may be easily identified.

As in Paper I, the power spectra of the raw data show many periodicities ranging from approximately 2000 km to 50000 km. The data were filtered so that periodicities in the following three ranges could be studied independently:

\[ 0 \leq \text{Class A} \leq 12000 \text{ sec } \theta \text{ km} \]
\[ 6000 \text{ sec } \theta \text{ km} \leq \text{Class B} \leq 20000 \text{ sec } \theta \text{ km} \]
\[ 12000 \text{ sec } \theta \text{ km} \leq \text{Class C} \leq 50000 \text{ sec } \theta \text{ km} \]

![Fig. 1. Enlarged positive prints of the Na D$_1$ and D$_2$ lines near disk-center are compared with the velocity and intensity fluctuations from the same regions derived from the microphotometer tracings.](image-url)
where $\theta$ is the average heliocentric angle of the region considered. To investigate possible variations between different sub-regions noted in Paper I, the three regions of the solar disk were again divided into three sub-regions for class A fluctuations and two sub-regions for class B fluctuations.

3. **The rms Fluctuations**

The relative rms line center intensity distributions against $\theta$ for the class A, B and C fluctuations are given in Tables II, III and IV as percentages of the mean line-center intensity at the particular value of $\theta$. The values for the class A fluctuations in Na D$_1$, Na 5688 and Mg 4571 are shown in Figure 2.

**TABLE II**

rms of filtered data (class A)

<table>
<thead>
<tr>
<th>$\bar{\theta}$ (in deg)</th>
<th>Na D$_1$</th>
<th>Na D$_2$</th>
<th>Na 5688</th>
<th>Na 5683</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>9.3</td>
<td>8.9</td>
<td>5.9</td>
<td>5.5</td>
</tr>
<tr>
<td>10</td>
<td>9.3</td>
<td>9.2</td>
<td>6.8</td>
<td>7.1</td>
</tr>
<tr>
<td>16</td>
<td>13.5</td>
<td>11.7</td>
<td>7.2</td>
<td>7.8</td>
</tr>
<tr>
<td>23</td>
<td>12.5</td>
<td>11.3</td>
<td>9.3</td>
<td>9.0</td>
</tr>
<tr>
<td>30</td>
<td>8.8</td>
<td>8.2</td>
<td>8.9</td>
<td>8.2</td>
</tr>
<tr>
<td>38</td>
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<td>6.9</td>
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<td>46</td>
<td>13.3</td>
<td>12.8</td>
<td>5.0</td>
<td>–</td>
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<td>54</td>
<td>11.4</td>
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</tr>
<tr>
<td>63</td>
<td>8.8</td>
<td>8.0</td>
<td>4.3</td>
<td>–</td>
</tr>
</tbody>
</table>

**TABLE III**

rms of filtered data (class B)

<table>
<thead>
<tr>
<th>$\bar{\theta}$ (in deg)</th>
<th>Na D$_1$</th>
<th>Na D$_2$</th>
<th>Na 5688</th>
<th>Na 5683</th>
<th>Mg 4571</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>6.4</td>
<td>5.4</td>
<td>5.4</td>
<td>4.3</td>
<td>6.3</td>
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<td>7.6</td>
<td>6.0</td>
<td>3.8</td>
<td>4.5</td>
<td>7.7</td>
</tr>
<tr>
<td>27</td>
<td>9.0</td>
<td>7.4</td>
<td>4.1</td>
<td>3.7</td>
<td>–</td>
</tr>
<tr>
<td>34</td>
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<td>5.1</td>
<td>4.7</td>
<td>3.4</td>
<td>–</td>
<td>7.7</td>
</tr>
</tbody>
</table>

**TABLE IV**

rms of filtered data (class C)

<table>
<thead>
<tr>
<th>$\bar{\theta}$ (in deg)</th>
<th>Na D$_1$</th>
<th>Na D$_2$</th>
<th>Na 5688</th>
<th>Na 5683</th>
<th>Mg 4571</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>5.2</td>
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<td>3.8</td>
<td>3.5</td>
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<tr>
<td>30</td>
<td>8.1</td>
<td>8.0</td>
<td>2.6</td>
<td>2.9</td>
<td>–</td>
</tr>
<tr>
<td>54</td>
<td>6.0</td>
<td>5.7</td>
<td>3.6</td>
<td>–</td>
<td>5.8</td>
</tr>
</tbody>
</table>
Fig. 2. Relative rms distributions against heliocentric angle are shown for class A fluctuations.

The rms values for the D line small scale structures range between 10% and 13%. Although there appear to be two maxima with a minimum at 30°, these could be due to local variations and we do not consider them statistically significant. More prominent maxima may be seen in the Na 5688 and Mg 4571 class A distributions but we cannot claim that they are statistically significant without further independent data. Qualitatively, however, these distributions resemble that of Edmonds (1962) for continuum intensity fluctuations more than those of Mg b and Na D.

For all lines the rms values decrease with increasing structure size. Further, for Na 5688 and Mg 4571, the maxima are less prominent for class B and class C fluctuations. The magnitude of the Na D rms is similar to those obtained for the Mg b lines but, because these observations were made at different times under different seeing conditions, we do not place too much importance on this result.

The digitising process should produce errors of no more than ±5% in the rms values. Although the resolution should be adequate to distinguish structures down to 2000 km (and even approached 1 arc sec for the Mg 4571 line), the rms values are also sensitive to the contrast transfer function of the optical system (see Steel, 1953; Giovanelli, 1961). For the 16" coronagraph and structures of order 4 arc sec, only about 10 to 15% of the contrast should be lost for heliocentric angles less than 60°.
Thus for structures greater than 3000 km, the rms values given here should not underestimate the true values by more than 20%.

4. Auto-Correlation Results

A selection of the auto-correlation curves for the brightness and velocity fluctuations is shown in Figures 3 and 4. For Mg b the periodicities observed could be classified into small scale structures (less than 10000 km) and large scale (greater than 20000 km). However, the curves of Figures 3 and 4 show peaks representing periodicities of order 6000, 11000, 16000 and 24000 km. The large scale periodicity can be derived only by considering the whole of region I. However, it is possible to check whether the smaller periodicities are characteristic of the Sun or merely of the particular data sample by considering regions I(b) and I(c) independently from region I(a), which was used to derive the curves shown in Figure 3(a). In fact, periodicities of 6000 and 11000 km are also indicated in these sub-regions but the auto-correlation peaks are not so well defined.

Small scale brightness fluctuations of periods near 6000 km and 11000 km may be

Fig. 3. Brightness and Doppler shift auto-correlation curves are shown in region I.
Fig. 4. Brightness and Doppler shift auto-correlation curves are shown in region II.

easily identified from the intensity fluctuations shown in Figure 1. In addition, several groups of bright peaks appear at points marked A, B, C and D on the diagram which are separated by distances of the order of 25000 km. It seems likely that they correspond to the 24000 km periodicity found in the auto-correlation curves and may well represent points at which the spectrograph slit intersects the chromospheric network as seen in Na D. Large upwards or downwards velocities (∼2 km/sec) are also observed near these points.

It is interesting to note that the brightness fluctuations for Na D₁ and D₂ bear a much closer resemblance to each than other did the fluctuations for Mg b₁ and b₂. In Paper I it was suggested that the difference could be explained by the approximately 250 km difference in the levels of formation in the b lines. The present results suggest that for the D lines this distance is much smaller.

5. Cross-Correlation Results

In Figure 5 a selection of the cross-correlation results for the Na D and Na 5688 lines
are shown. Positive correlation at zero lag represents brighter than average elements moving towards the observer, although it should be emphasised that the interpretation of the line-center Doppler shift as a vertical mass motion at that point in the atmosphere is perhaps a dangerous oversimplification of a complex multi-dimensional

Fig. 5. Cross-correlation curves are shown for the Na D and 5688 doublets in the regions indicated. The full curves represent the Na D results, the dotted curves the Na 5688 results.
problem in radiative transfer. For small scale structures at disk-center the cross-correlation is weak but positive in Na D. For class C fluctuations (large scale) the D lines and the 5688 lines exhibit opposite correlations in region I, similar and strongly negative correlation at zero lag in region II and opposite correlations for class B structures in region III. (In region III, cosθ is of order 0.5 and thus structures of order 25000 km are filtered into class B rather than class C.) Here the D line curve is similar to the corresponding curve for the Mg b lines which was interpreted as evidence that the large scale brightness fluctuations in the b lines are closely associated with the chromospheric network and the supergranule motions. Since we have already made a tentative association between the large scale (25000 km) periodicities and the chromospheric network in Na D, a similar explanation seems likely here. However, without a more detailed analysis, it is not possible to predict the sign of the correlation which one might expect. The opposite correlations of the D lines and the 5688 line in regions I and III and the negative D-line correlation in region II stress the need for a two-dimensional radiative transfer analysis of models of the supergranule cells in these lines.

In order to investigate the significance of these results, we again turn to the actual brightness and velocity tracings for the Na D lines. By inspecting these tracings for the Mg b lines (see Paper I in Solar Phys. 14, 31) it was found in Paper I that one could distinguish regions which appeared to display quite strong negative or positive correlation extending over ranges of about 25000 km. This was put forward as a possible explanation of the rather inconsistent results obtained for the cross-correlation coefficients for the small scale fluctuations when calculated over an entire sub-region of order 80000 km. An examination of Figure 1 suggests that similar regions of positive or negative correlation might exist in the Na D line structure although they are less obvious than those for the Mg b fluctuations. It is perhaps more significant that the correlation changes abruptly at points which we have tentatively identified as intersections of the slit with the chromospheric network in Na D and thus, as Simon and Leighton (1964) have shown, with the supergranule boundaries. This is particularly noticeable near B and C. At each point one brightness maximum is associated with a large positive Doppler shift and one with a negative shift. In Paper I it was suggested that these discontinuities in the small scale cross-correlations are in some way associated with the supergranule cells, and the Na D results provide some support for this suggestion. However, without a more detailed understanding of the nature of these small scale features, it is not possible to say how the oppositely directed horizontal motions in different supergranule cells might affect the line-center shifts of the small scale features within these cells. Thus our present concern is to discuss whether this change in sign of the small scale cross-correlation is a real solar effect or whether it arises only from an inadequate statistical sample.

6. The Range of the Cross-Correlation

In an attempt to quantitise the discussion somewhat we calculated the actual Mg b2
cross-correlations at zero lag over the ranges which we had, by inspection, classified as (i) negative, (ii) uncorrelated, (iii) negative, and (iv) weak positive (see Figure 6). The resulting numerical values of (i) $-63\%$, (ii) $-3\%$, (iii) $-54\%$, (iv) $+20\%$ were quite gratifying. However, because the ranges were determined by visual inspection, these calculations can give little objective support to our suggestion that the range of good correlation (of either sign) is of order 25000 km. Further, the corresponding results for Na D were less satisfactory.

In seeking a more satisfactory method, we calculated the cross-correlation coefficients over a great variety of different ranges within the sample. After a variety of attempts to organise the resulting mass of numbers in some way which distinguishes regions of good correlation from uncorrelated regions, the following method was used, and the results are shown in Figures 6, 7 and 8. The cross-correlation coefficients at zero lag are calculated over ranges (on the disk) from 5000 km to 50000 km in increments of 1250 km, and extend beyond the sub-region shown in Figure 1 to include the whole of region I. The results for the several ranges having a common starting point are grouped together to construct a single curve on the diagram. Thus the abscissa of the small rectangle at the left hand end of each curve represents the

![Diagram](https://example.com/diagram.png)

Fig. 6. Curves show cross-correlation coefficients at zero lag for the Mg b₁ data. In each curve the coefficients are calculated over ranges which have one common end point represented by the abscissa of the small rectangle at the start of the curve. At each point on a curve the abscissa specifies the other end of the range and the ordinate represents the cross-correlation coefficient calculated over that range.
common starting point, while the ordinate at each point on a curve represents the cross-correlation coefficient calculated over the range whose end point is given by the abscissa. A new curve is obtained by choosing a new starting point 10000 km from the previous starting point and repeating the process.

It might be objected that, by this procedure, local conditions at the left hand end of each curve are more heavily weighted than at the right hand end. This could have been avoided by a forward and back averaging technique but, in fact, it turns out to be an advantage for the ordinate of the five curves at any point will provide different information about the correlation conditions at that point. We use this information to suggest the following criteria: (i) If the correlation is weak or negligible, coefficients calculated over short ranges (i.e. near the start of each curve) may be quite large (positive or negative) but decrease rapidly as the range increases along the curve. (ii) Regions of significant correlation are detected when all the curves through the region show correlations of the same sign. (iii) Significant changes in the correlation are detected when all curves show a sudden change of gradient and a change of sign.

The application of these criteria to the curves for Mg b₂ in Figure 6 shows that there are three regions of significant correlation. From R to S (30000 km) the corre-
lation is positive, from $T$ to $U$ (20000 km) negative, and from $U$ to $V$ (33000 km) again positive. The noise inherent in the data prevents any of the calculated coefficients exceeding 45% but the sharp gradients shown by all curves at $T$ and $U$ and the uniform sign of the correlation curves within these regions argue for their significance. By contrast, the region $ST$ and, more particularly, $QR$, are good examples of uncorrelated regions.

Curves for Mg b$_2$ shown in Figure 7 may be analysed in the same way. Between $P$ and $R$ the negative correlation is much stronger than for Mg b$_1$ and to the right of $R$ only the negative correlation between $T$ and $U$ can be distinguished with any reliability. These differences may be ascribed to the different heights of formation of Mg b$_1$ and b$_2$.

Figure 8 shows the curves for Na D$_1$. Although the correlation appears to be weak or random over a large part of the sample (including the region marked as UV, which corresponds to that shown in Figure 1), between $X$ and $W$ (25000 km) there does exist a region of significant positive correlation. The pattern for Na D$_2$ is similar and is not shown separately.

Although we feel some confidence in the usefulness of this classification scheme, we cannot yet claim any statistical significance for the results so far obtained. The
pattern of regions of positive or negative correlation extending over some 30000 km, either adjacent to each other or separated by uncorrelated regions, is quite consistent with the hypothesis that they are related to the random intersection of supergranule cells by the spectrograph slit. However, the hypothesis can be adequately tested only by designing a more complex set of observations in which the position of the slit in relation to the supergranule network can be determined. Although inherently more difficult, the present results strongly suggest that such a program should be attempted.

7. The 5 min Oscillations

Since the aim of this series of observations is to obtain optimum spatial resolution at moments of very good seeing, no time sequence studies have been attempted. However, these observations are complementary to time series observations such as those of Tanenbaum et al. (1969) in which the spatial resolution is necessarily reduced. These authors have studied both photospheric and chromospheric lines, including Mg b2 and Na D1, and find 5 min oscillations which, they suggest, are travelling waves in the photosphere and standing waves in the chromosphere. They conclude that “the observed amplitudes and sizes of the oscillations are consistent with a picture of many small oscillating elements superposing to give the appearance of larger ones. The oscillating elements appear on the average to be smaller than our effective resolution, 6000 km.”

The present observations can easily resolve structures down to 2 arc sec and probably down to 1000 km and it is interesting to consider the possibility that the small scale brightness and velocity fluctuations found here may correspond to the small oscillating elements postulated by Tanenbaum et al. Although their observations describe brightness and velocity fluctuations in time at some standard position while ours provide an instantaneous picture at many points along the slit, one would expect that the phase difference in time of 100°, which they find, should effectively displace brightness and velocity peaks in an instantaneous picture. Thus the observed cross-correlation should be rather weak, as indeed it is in some regions of the Mg b and Na D fluctuations shown here. However, regions of strong negative or positive correlation extending over some 25000 km do not conform to this pattern. Even allowing for the very different methods of observation, it would be hard to argue that the large fluctuations near points B and C in D1 (Figure 1) are 100° out of phase in time. Indeed, to the right of B and the left of C the phase angle must be close to zero while to the left of B and to the right of C the phase angle is nearer 180°. Further, just to the left of D we find in both lines a run of three complete oscillations which appear to be 180° out of phase.

It is worth noting that the velocity and brightness amplitudes found by Tanenbaum et al. (typically ~150 m/sec and ~½%) are much less than those reported here and the differences noted above may be due entirely to resolution. However, we cannot agree that the small oscillating elements postulated by Tanenbaum et al. have the common phase angle of 100° which they find for the superposed structures. Since this
phase angle is the basis of their argument that these oscillations are standing waves in the chromosphere, the point is of some interest. Evans et al. (1963) presented earlier power spectra showing the five minute oscillations, but they emphasised that their results are related to the brightness and velocity field as a whole and should not be confused with the Fourier representation of the individual perturbations. In fact, they suggest that "individual perturbations of different origin and physical nature may be present simultaneously." The results of Tanenbaum et al. indicate that the 5 min oscillations are still in evidence when spatially averaged over 6 arc sec, while our own indirect evidence supports the suggestion of Evans et al. that the individual features may have somewhat different properties.

8. Discussion

The original purpose of this project was to obtain center-limb rms intensity distributions for a range of photospheric and chromospheric lines. However, the variations in the properties of the small and medium size fluctuations between two disk-regions at the same heliocentric angle and from line to line at a given position was an unexpected result. It immediately poses the important question whether these results are a characteristic property of the Sun or whether they arise only from the limited sample size of the data. This question was discussed in Section 8 of Paper I and has been further explored here. In practical terms, we would like to know whether these results would be reproduced on another spectrum of the same line at the same value of $\theta$ on another day.

Unfortunately we cannot give a definite answer at this stage. The program was designed to obtain one run for each line under optimum seeing conditions and indeed we were fortunate in obtaining the data which we have presented here in the limited time available. It was only after the preliminary analysis of the data had been completed that the importance of the question of the day-to-day reproducibility became apparent. A recent attempt to obtain further data on the Mg b lines at Kitt Peak Observatory was defeated by poor seeing conditions but it is obviously desirable to attempt further observations, including slit-jaw filtergrams in the lines, as soon as possible.

At this stage we would expect that real variations from point to point and day to day on the Sun might cause variations in the rms intensity fluctuations of up to $\pm 5\%$ (of the mean line-center intensity at disk-center) and thus the details of the center-limb distributions, such as those shown in Figure 2, could not be considered reliable. Nevertheless, if one includes Edmonds' (1962) distribution for the photospheric continuum, the data range from that level through the weak photospheric lines of Mg 4571 and Na 5688 to the low chromospheric lines of Na D and Mg b and the possibility of a consistent picture does begin to emerge from a comparison of these distributions. Thus we find that while the continuum distribution has a slight minimum at 24° and a prominent peak at 53°, Mg 4571 and Na 5688 have no minimum but peak at 40° and 20° respectively. Despite the difficulties discussed above it does appear that the
distributions for the chromospheric lines are different in character. There does not appear to be a definite maximum in the distributions for either lines although both show a tendency to decrease beyond 40°.

On the basis of Edmonds’ distribution, a two-dimensional model of temperature fluctuations in the photosphere was proposed by Wilson (1969a, b). A feature of the model was the large maxima in the temperature fluctuations near τ_{5000} = 0.7. In a simple-minded way the distributions for the photospheric lines are not inconsistent with this model provided one assumes that these lines are formed in LTE at successively higher levels in the photosphere. However, we again emphasise the need for further independent observations. More recently Cannon (1971) has investigated two-dimensional models for the formation of the Na D and Mg b lines. Because of the problems described above he has used only the order of magnitude of the rms values of the different lines but has not included the center-limb variations. However, his analysis shows that it is just these details which will permit one to distinguish between various inhomogeneous models of the chromosphere.

With regard to the sudden changes of the brightness velocity cross-correlations we would be surprised if future observations did not show a similar result; i.e. regions of either positive or negative correlation extending over ranges of order 30000 km, interspersed with regions of negligible cross-correlation. This result was first suggested from the detailed analysis of a subregion (region Ia) of Mg b_2 and it was subsequently supported when the whole of region I was investigated for both Mg b_1 and b_2 and a similar region at disk center for Na D_1 and D_2, using the methods described in Section 6 above. Thus, although our sample is not sufficient to assert this result with confidence, we do feel that it well justifies further observational work to test it.

9. Conclusion

These observations have highlighted the day-to-day and point-to-point variability of the statistical properties of the small scale features of the solar atmosphere. It is clear that reliable center-limb rms data for any line can only be obtained from several independent runs on different days preferably by different observers. Despite these difficulties, the theoretical importance of this type of data makes it all the more desirable that observations of this type be continued.

Acknowledgements

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References