THE HORIZONTAL VARIATION OF TEMPERATURE IN
THE LOW SOLAR PHOTOSPHERE

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Abstract. Observations of the rms intensity fluctuations in the continuum obtained by Pravdjuk et al. (Solnechnye Dannye, No. 2, p. 70, 1974) from white-light photographs made with the Soviet Stratospheric Solar Observatory are analyzed to obtain a horizontal temperature-fluctuation amplitude as a function of depth. The results indicate that temperature fluctuations increase with depth monotonically from a small value at \( \tau_{5000} \approx 0.5 \) (cf. Figure 2). The initial rise of \( \Delta T \) appears quite steep, having a slope of approximately 20 K km\(^{-1}\). The model of Wilson (Solar Phys. 9, 303, 1969) is incompatible with the data. Convective flux in the present model is approximately 6% of the total flux at \( \tau_{5000} = 1 \).

1. Introduction

The horizontal variation of temperature with depth, \( \Delta T(z) \), in the photosphere is an important quantity for determining the convective flux in the visible layers of the sun and thus provides a check on models of convection. A widely used model for \( \Delta T(z) \) has been that of Wilson (1969), which is based on the reduction of Stratoscope data (Schwarzschild, 1959) by Edmonds (1962). However, a recent study by Altrock and Musman (1976) has called that model into question. They find a monotonic increase of \( \Delta T \) with depth with an amplitude of approximately 140 K at 14 km above \( \tau_{5000} = 1 \), vs the maximum \( \Delta T \) of approximately 900 K found by Wilson (1969) at that height. A theoretical study by Musman and Nelson (1976) is also in qualitative agreement with Altrock and Musman (1976).

In an attempt to resolve this disagreement, I have analyzed the data of Pravdjuk et al. (1974) (hereinafter referred to as PKA). These data are rms intensity fluctuations in the continuum from the center to the limb, \( \delta I(\mu) \), where \( \mu = \cos \theta \), and are taken from white-light pictures made with the Soviet Stratospheric Solar Observatory. Thus, the data are obtained in a manner similar to the Stratoscope data, and the method of analysis I will follow will be similar to that utilized by Wilson (1969).

2. The Data

PKA tabulate values of \( \delta I(\mu) \) at \( \lambda \approx 4600 \text{ Å} \) from \( \theta = 0 \) to 85°. Only the best frames were used. The data were corrected for film grain and measurement errors but not instrumental smearing. The values presented are taken from two different flights, and the results in the range \( \theta = 30 \) to 50° (from the later flight) have been scaled (divided by 1.33) to the results outside that range from the earlier flight.
Fig. 1. rms intensity fluctuations as a function of disk-position angle. Circles: data of Pravdjuk et al. (1974); solid line: 'best-fit' solution of this paper. Uncertainty bars are given for data (see text for discussion).

Thus, there appears to be a systematic uncertainty in the amplitude of all values of $\delta I$ of at least 33% of the local value.

The data are presented in Figure 1. The uncertainty bar at $\theta = 15^\circ$ represents $\pm \sigma$, where $\sigma$ is the standard deviation of the values of $\delta I$ given by PKA for nine areas with $\theta < 30^\circ$. The other uncertainty bar indicates the range in values for the two values presented at that approximate value of $\theta$. An 'eyeball' estimate of the scatter beyond $\theta = 50^\circ$ (from Figure 3a of PKA) indicates that the value of $\sigma$ continues to increase with $\theta$. A smooth curve has been drawn through the observed data points by PKA. I do not present data (or the results of the analysis) beyond $\theta = 70^\circ$. This is because both Edmonds (1962) and PKA indicate that beginning at approximately $\theta = 80^\circ$ the nature of the inhomogeneities seen in the continuum undergoes a fundamental change. The granules begin to disappear, and large-scale, diffuse non-uniformities begin to account for the measured intensity fluctuations. Although the nature of these non-uniformities is not clear, it appears that they represent a different class of structures from granules and should not be included in a study of granules.

Finally, it is of interest to note that the brightness distribution found by PKA is distinctly asymmetric and implies that the ratio of areas of bright and dark elements is 0.80 at the center of the disk. This confirms the results of Parvey and