RMS VELOCITIES IN SOLAR ACTIVE REGIONS

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ABSTRACT. Spectrograms taken at Sacramento Peak were analyzed by means of power analysis. The vertical and non-vertical rms granular velocity field in active Solar regions shows a significant reduction compared to that of the non-active regions. We explain this reduction in terms of enhanced magnetic fields in active regions and the resulting inhibition of small-scale velocity fields.

The interaction of the small-scale velocity fluctuations with the magnetic field in the overshoot layers prove to be of central significance for the physics of the solar atmosphere: the heating of the chromosphere and the bright points (filigree) in the photosphere are two different phenomena which can be considered as manifestations of this interaction.

To determine the influence of the magnetic field on the velocity fluctuations in the photosphere, we compare the power spectra of the velocity fields of active with those of non-active regions. Here, the non-active regions are regarded as being free from magnetic flux and, therefore, can be used as reference for this comparison.

Mattig and Nesis (1974) showed that there is a difference between the power spectra of active and non-active regions; they furthermore investigated the height dependence of the granular rms velocity of active and non-active regions by means of the line core and line wings of the absorption line. Mattig and Nesis (1976) repeated this analysis with new material but the results seemed to be in conflict to those of the previous study. Now, about ten years later, we analysed new spectrograms obtained at Sac Peak observatory at two different positions on the disc of the Sun, at \( \cos \theta = 1.0 \) and \( \cos \theta = 0.8 \). Thus, we can compare active and non-active regions and their variation with height in the photosphere for the vertical \((\cos \theta = 1.0)\) as well as for the non-vertical \((\cos \theta = 0.8)\) velocity fields. In this investigation the variation of the velocity fields with height is calculated by means of the absorption lines 6496 Å and 5576 Å. Using the intensity contribution functions of these lines we found the line formation to be at a height of 175 km and 325 km above \( r_{5000} = 1.0 \), respectively. The layers at about 325 km level are in the following denoted as the higher layers, those at about 125 km as the deeper photospheric layers.

The calculated power spectra of the active and non-active regions are shown in Figs. 1 and 2 for \( \cos \theta = 1.0 \) and \( \cos \theta = 0.8 \), respectively. Here, we realize that the power spectra of the active regions (A.R) show smaller values than the power spectra of the non-active regions (N.A.R), regardless of the heights in the photosphere and the position on the

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Figure 1: Velocity power spectrum

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\[ \lambda = \text{6496 Å} \quad (\cos \theta = 0.8) \]

\[ \lambda = \text{5576 Å} \quad (\cos \theta = 0.8) \]

Figure 2: Velocity power spectrum
solar disc. Using these power spectra we calculated the $V_{tot}$, the total rms velocity. The values are given in Figs. 1 and 2.

To determine if there is a difference between the velocity variations with height in the active and the non-active regions we calculated $V_{tot}^A / V_{tot}^{N,A}$ in the deeper and higher layers. We find that the value of $V_{tot}^A / V_{tot}^{N,A}$ does not change with height, which demonstrates the similarity of the variation of $V_{tot}$ in the active and non-active regions. This does not depend on the position on the solar disc. In Figs. 3 and 4 the height dependence of the velocity $V_{tot}$ is shown for the active and non-active regions.

The range of small-scale rms velocity $V_{gran}$ in the total velocity $V_{tot}$ is marked by the shaded areas in the power spectra shown in the Figs. 1 and 2. $V_{gran}$ was not calculated directly. To estimate the variation of $V_{gran}$ with height, we compared the shaded areas in the deeper layers (for 6496 Å, Figs. 1 and 2, above) with those of the higher layers (for 5576 Å, Figs. 1 and 2, below). Normalizing the values of the deeper layers to 1, we found a decrease of $V_{gran}$ at the higher layers by a factor of 0.67 in the non-active regions, and by 0.57 in the active regions for $\cos \theta = 1.0$, and by factors of 0.84 and 0.69, respectively, for $\cos \theta = 0.8$. The comparison of $V_{gran}$ in the active regions at $\cos \theta = 1.0$ and $\cos \theta = 0.8$ (Figs. 3 and 4) shows that the decrease with height is larger at $\cos \theta = 0.8$ than at $\cos \theta = 1.0$.

Summarized, we can say that the gradient of the velocity in the active and those in the non-active regions depends sensitively on the spatial structuring of the velocity field. In the case in which the velocities correspond to a velocity field which is represented by all spatial wave numbers there is no difference in the gradients between active and
non-active regions neither for the vertical nor for the non-vertical velocity fields (Figs. 3 and 4). However, this is not the case for the small-scale (3.5'-1.6') velocity field. Here, we observed a difference between the velocity gradients in the active and the non-active regions (0.57 and 0.67, respectively). This difference is enhanced if we consider the velocity gradients calculated for the case of \( \cos \theta = 0.8 \) (0.85 and 0.69, respectively).

Now, the faster decay of the small-scale velocity in the active regions can be interpreted as an emerged energy deficit in the higher layers, which seems to be larger at \( \cos \theta = 0.8 \) than at \( \cos \theta = 1.0 \). We interpret this finding as an enhanced loss of kinetic energy with respect to the non-active region. A first estimation of the variation of the kinetic energy \( (\rho v^2) \) with height in the active regions reveals a value that is 30% smaller than the corresponding value of the non-active region. This energy deficit could be due to the influence of the horizontal velocity. This has to be shown by further measurements towards to the limb of the solar disc.

References
Discussion

KOUTCHMY — Could you specify the method used to measure velocities, and also how you remove the 5-minute oscillation?

NESIS — The velocities correspond to the measured rms Dopplershift in the core of the line. The 5-minute oscillations were removed by filtering the spatial power spectrum.

DEUBNER — A remark: since motions across magnetic field lines are impeded more efficiently at lower $\beta$-values, i.e. at greater heights, the relatively stronger gradient of the rms velocities in active regions at $\mu = 0.8$ appears easy to understand qualitatively.

NESIS — This is a possible explanation.