NEW RESULTS ON THE HYDRODYNAMICS OF THE OVERSHOOT LAYERS IN "ACTIVE REGIONS" 1

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ABSTRACT. We present here, preliminary results on the variation with height of the cross-correlation and coherence between the intensity fluctuations of the continuum. $\gamma_{\text{5000}} = 1.0$, and the Doppler-velocity fluctuations measured at different levels (heights) in the photosphere. This investigation concerns the intensity and velocity fluctuations which were measured directly outside a sunspot observed near the center of the solar disc. The analysis was based on spectrograms obtained at Tenerife on 1986 with the newly installed Gregory telescope. Our investigation shows a significant variation of the intensity-velocity and velocity-velocity cross correlation and its associated coherence with height in the photosphere.

The overshoot layers of the solar atmosphere are the layers where the interaction of the magnetic field with the velocity field of convective origin can be investigated. So far, the investigation of this interaction concerned only comparison of the active and non-active regions, especially the rms velocities and their variation with height (Nesis et al. 1988a). Here, non-active regions are used as reference to investigate any changes in the active regions. But the interaction between magnetic and velocity field affects not only the rms values of the velocity field: it also changes substantially its spatial "structuring": it modifies the scales of the area with upflow or downflow which are included in the observed velocity field area.

In this investigation our interest lies on the velocity field of active regions, especially, on its spatial structuring and on the variation of this structuring with height in the photosphere. For this reason, we observed the velocity field directly outside of a sunspot, considering the regions nearby the sunspot as active regions.

The velocity field was measured as Doppler shift at the core of absorption lines. The intensity fluctuations were measured at the continuum and, thus, represent the spatial inhomogeneities mainly due to the granulation. The spectrograms which we used in this investigation were obtained with the newly installed Gregory Coude-Teleskop (Tenerife), and included absorption lines of different strength in the wavelength range $\lambda 6493-6497$ Å, which enable us to determine the Doppler velocity fluctuations at different levels (heights) in the atmosphere. Because the spectrograms were taken near

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the center of the solar disc the results concern only the vertical rms velocity fields near a spot.

In the following, we enumerate different levels (heights) in the photosphere according to the strength of the absorption lines, which we used for measuring of the Doppler velocity. In our notation, lines 4, 6, 8, and 5 refer to the absorption lines with central intensities 0.73, 0.65, 0.47, and 0.24, respectively. Lines 4, 6, 8, and 5 represent, therefore, in this order, a sequence of increasing height in the photosphere. According to their contribution functions the lines 4, 6, and 8 represent in a first approximation the first 200 km, above \( \tau_{5000} = 1.0 \) and line 5 represents the layers around the temperature minimum (500 km).

Insight to the structuring of the velocity field and its relation to the intensity field of the continuum, \( \tau_{5000} = 1.0 \), can be obtained by considering the cross-correlation and the related coherence. From the coherence we obtain information on the value of the similarity of the correlated fields, especially, for any spatial wavelength.

Using the coherence analysis (see Nesis et al., 1988b) we calculated the cross correlation as well as the coherence between the intensity field of the continuum and the velocity field measured at different levels in the photosphere. Furthermore we calculated the cross correlation and the coherence between the velocity field of the deepest layers (line 4) and those fields of the higher layers (lines 6, 8, and 5): here, the variation of the coherence at the different layers demonstrates the change of the velocity structuring with height in the photosphere. On the other hand, the velocity–intensity coherence reveals the relation of the velocity fields of the different levels to the intensity field of the continuum and therefore to the granulation. Thus, this investigation enables us to have insight to the "fragmentation" of the spatial velocity structures, which are related to the granulation, as a function of height in the active regions.

Fig. 1 shows the variation of the cross correlation between the intensity fluctuations of the continuum and the Doppler velocity fluctuations measured at the levels represented by lines 4, 6, 8, and 5. In this figure and those which follow, one step in the cross correlation corresponds to 0"16. We see, here, in the case of line 5 the abrupt disappearance of the cross correlation between intensity and velocity fluctuations, which demonstrates the total decoupling of the velocity structures of the higher layers from the continuum inhomogeneities. By contrast, in the case of lines 4, 6, and 8 the cross correlation retains its value and demonstrates, thus, the similarity between the velocity structures of the first 200 km above \( \tau_{5000} = 1.0 \) and the intensity structures of the continuum (granulation).

In Fig. 2 the coherences associated with the cross correlations of Fig. 1 are shown. We realize the disappearance of the coherence between intensity and velocity of line 5, an expected result. Besides, we find an enhancement of the coherence between the intensity field of the continuum and the velocity field of line 8 in the range of small scales (1"7—0"5), which is not found in the intensity–velocity coherence of lines 4 and 6: their coherence disappears for spatial scales < 2"0. This enhancement of the coherence could be interpreted as a result of the gradual disappearance of large granulae with height and the generation of small scale velocity structures in the higher layers—this under the assumption that the intensity field of the continuum includes such small scales.

Figs. 3 and 4 demonstrate the cross correlation and the related coherence
Figure 1: Cross Correlation between intensity and velocity fluctuations of the continuum and the velocity fluctuations at different levels in the photosphere (lines 4, 6, 8, and 5).
Figure 2: Coherence of the intensity fluctuations of the continuum and the velocity fluctuations at different levels in the photosphere (lines 4, 6, 8, and 5). x: represents a relative number.
Figure 3: Cross Correlation between the velocity field fluctuations at various levels in the photosphere. Line 4 is formed deeper than line 6 and line 8.
Figure 4: Coherence between the velocity field fluctuations of the deepest level (line 4) and higher levels.
Figure 5: Velocity-velocity cross correlation between the highest and deeper levels.

Figure 6: Velocity-Velocity coherence between the highest and deeper levels.
between the velocity fluctuations of the deepest layer (line 4) and the velocity fluctuations of the higher levels (lines 6 and 8). Here, we see the conservation of the high correlation with height within the first 200 km above \( \tau_{5000} = 1.0 \). This behaviour corroborates the coherence in Fig. 4, which is associated with the cross-correlation in Fig. 3. We see here a high coherence for all spatial wave number down to 1".4. However, the velocity fields of lines 4 and 8 and those of lines 6 and 8 reveal an enhanced coherence down to 1".0.

Figs. 5 and 6 illustrate the cross correlation and the associated coherence between the velocity fields of the layers that lie below 200 km above \( \tau_{5000} = 1.0 \) (lines 4 and 6) and the velocity field above these layers (line 5). We realize here the strong decrease of the cross correlation and the corresponding decrease of its associated coherence. Furthermore, we see a shift of the coherence towards the large structures (\( > 3".5 \)).

To summarize, the velocity field of the layers beyond 200 km above the continuum, \( \tau_{5000} = 1.0 \), does not show any similarity neither to the intensity of the continuum nor to the velocity field of the first 200 km. This behaviour of the velocity of the active regions is similar to that of the non active regions (see Nesis et al. 1988b). Concerning the coherence of the small scales (\( \leq 1".3 \)) of the velocity field of the layers which are located 200 km above the continuum, demonstrate a significant correlation to the intensity field of the continuum and the velocity field of the deepest layer. We do not find a similar behaviour in the coherence analysis of the nonactive regions (Nesis et al. 1988). We interpret this finding as the result of forced fragmentation of the granules in the area near the sunspot. But, whether this fragmentation could be attributed to any action of the magnetic field on the velocity field is not yet clear: to investigate this question we need more observations.

References


Discussion

P. Mein: You find a very low coherence between the intensity of the continuum and the velocities in the line formed in the upper layers. Is there enough energy left in the power spectrum of velocities after removal of 5-min oscillations? Can we still speak of overshoot structures at the upper level?

A. Nesis: There are small structures with velocity power also after the removal of the 5-min oscillations. However, we cannot speak for overshoot structures of convective origin.

F. Deubner: I understand that a running mean spatial filter serves to extract the larger spatial scales (which are) strongly contaminated by the 5-min oscillations from the data and thereby enhances the cross-covariance at zero spatial lag. But it has no impact on the spatial coherence spectra you have shown, since it reduces the power of convective motions at large spatial scales just as well.

A. Nesis: I agree with you.

M. Knölker; Was it a singular spot?
A. Nesis: Yes.