ANALYSIS OF A RELATION BETWEEN SUBPHOTOSPHERIC PLASMA FLOWS AND PHOTOSPHERIC CURRENT KERNELS

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ABSTRACT

Very recently the subphotospheric plasma flows below the sunspots and active regions were revealed by the Time-Distance method of local helioseismology. In this paper we have studied positions of current kernels obtained from vector magnetograms together with maps of kinetic helicity and vorticity at several depths below the photosphere. Vector magnetograms obtained from Marshall Space Flight Center Solar Physics Group internet archive were used together with 3-D velocity fields obtained by Time-Distance method from SOHO/MDI data. The 3-D plasma flow velocities were provided by Dr. Kosovichev. We have found that maxima of vorticity are within an active region and are located at the depth of 3.0 Mm below the photosphere. Maxima of kinetic helicity are dominant within the active region in a depth range 1.8 - 4.5 Mm. The positions of vertical current kernels do agree with positions of observed flare kernels in UV continuum as it is widely believed. The maxima of kinetic helicity are not located directly below the vertical current kernels but they are still in their vicinity.

Key words: plasma flow, active region, flare.

1. INTRODUCTION

Leka et al. (1996) showed that new emerging flux in active region carries electric currents of subphotospheric origin. The question how these currents are produced is still open.

Zhao et al. (2001) applied the Time-Distance (T-D) method of local helioseismology to SOHO/MDI data and revealed subphotospheric plasma flows below the sunspots and active regions. In this contribution we have tried to look for any connection between vertical electric current kernels observed in photosphere and vorticity and kinetic helicity of plasma flows below an active region. We have used the set of 3-D subphotospheric velocity fields derived by T-D method which Dr. Kosovichev kindly provided us with and vector magnetograms from MSFC tower vector magnetograph obtained from their internet archive.

2. DATA AND ANALYSIS

T-D method is able to reveal plasma flow structure of active region satisfactorily down to the depths about 15 Mm below the photosphere. The data of 3-D subphotospheric plasma flows covered the emergence and decay of active region NOAA 9393: i) March, 4 – 8, 2001 - emergence of the active region, ii) March, 25 - April, 1, 2001 and iii) April, 24 – 26, 2001 - decay of the active region. The flow velocities of subphotospheric plasma were obtained by analysis of sets of 8.5 hr series of SoHO/MDI dopplergrams. The 8.5 hr intervals covered usually several flares and therefore we cannot distinguish any subtle changes in velocity pattern due to particular flares. Anyway, evolution of an active region in the convection zone leads to emergence and decay of magnetic flux in photosphere. Solar corona then responds to the changes of magnetic flux in the photosphere by reorganizing its structure. This reorganization may take some time and is usually associated with flares. We were interested then if we can see any special vorticity and kinetic helicity patterns situated close to the places where the flares occurred in active region NOAA 9393 and 9433.

Using the 3-D velocities of plasma flow below the photosphere we have constructed maps of vorticity \((\nabla \times \mathbf{v})\) and kinetic helicity \((v_z, (\nabla \times \mathbf{v})_\phi)\) in depths ranging from 0.77 to 11.80 Mm below the photosphere. MSFC vector magnetograms were used to calculate vertical current kernels in NOAA 9393 at three days: March, 27, 2001 at 19:41 UT and on April, 25 and 26, 2001 at 13:55 UT, 15:16 UT, respectively. We decided to use only those vector magnetograms when the analysed active region lay not too far from central meridian. We had no precise information of field of view of MSFC vector magnetograms so in addition to them we have also used full disk SoHO/MDI longitudinal magnetograms. At first we have corrected the longitudinal MSFC component for P angle between celestial North and solar North. Then we rescaled the MSFC longitudinal component to MDI pixel
size and transferred it appropriately to fit to the same flux pattern at SoHO/MDI longitudinal magnetogram. This way, we have constructed ‘auxiliary MDI full disk images’ which contained particular part of longitudinal MSFC component. These ‘auxiliary MDI full disk images’ were then projected using the same projection as was used for computing the flow velocities from MDI data. The same method was used for images of transverse component and azimuth of transverse component of all used MSFC data. The resulting vertical current kernels were computed only from those parts of projected ‘auxiliary MDI full disk images’ containing only MSFC data.

We assumed that the uncertainty of longitudinal component of magnetic field strength is about 50 G and for the transverse component we took 100 G, therefore we considered the current kernels in field strengths higher than previously mentioned uncertainties. The estimated uncertainty of vertical current $J_z$ was ±0.01 A m$^{-2}$. The contours of $J_z$ depicted in figures are 0.025 A m$^{-2}$.

3. RESULTS AND DISCUSSION

- Vorticity: We have found that striking maxima within an active region as seen at the surface and are located at the depth of 3.0 Mm below the photosphere, Fig. 1. Above 3.0 Mm the maxima are not so striking and supergranules are visible, Fig. 1.

- Helicity: Maxima of kinetic helicity are dominant within the active region as seen at the surface in a depth range 1.8 - 4.5 Mm. From about 6.4 Mm there is nearly no difference between the kinetic helicity structure within and away from the active region Fig. 2, 3.

- Vertical current kernels: The positions of vertical current kernels agree with positions of the observed flare UV kernels quite well, Fig. 6, but the maxima of kinetic helicity are not located directly below the vertical current kernels. Although, they are still located in their vicinity, Fig. 4, 5. Not all the kinetic helicity maxima, for which we suppose might be associated with $J_z$, are located at the same depth below the photosphere, cf. Fig. 2, 4.

The appearance of vorticity and kinetic helicity maxima below the active region in 1.8 - 6.4 Mm depth range is not so surprising. Zhao et al. (2001) showed that this is the typical scale of flow structure observed below the simple sunspot. According to this study we are not able to prove that location of maxima of kinetic helicity below the studied active region are associated with local vertical current kernels observed in photosphere.

REFERENCES


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Figure 2. Kinetic helicity map of active region NOAA 9393 on March 27, 2001 at 20:00 UT at 3.0 Mm (left) and 6.4 Mm (right).

Figure 3. Kinetic helicity map of active region NOAA 9433 on April 26, 2001 at 12:00 UT at 3.0 Mm (left) and 6.4 Mm (right).
Figure 4. Comparison of vertical current kernels at 19:42 UT (left) with local maxima of kinetic helicity at depth of 4.5 Mm (right) on March 27, 2001.

Figure 5. Comparison of vertical current kernels at 15:16 UT (left) with local maxima of kinetic helicity at depth of 4.5 Mm (right) on April 26, 2001.