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Propagation and reflection of nonlinear Alfven wave in the solar chromosphere

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It has been suggested that Alfvén waves, generated in the photosphere and propagating along the magnetic flux tube, can carry enough energy to the low-plasma-beta region in the upper chromosphere and the dissipation of waves is one of the possible mechanisms to heat the solar chromosphere. Temperature of the chromosphere is low and the plasma gas is partially ionized. The collisions between plasmas and neutrals cause additional diffusion of the magnetic fields, which is called ambipolar diffusion. On the other hand, the compressible waves are generated by the nonlinear effect of the magnetic pressure associated with the Alfvén waves propagating upwards from the photosphere, and form shock waves in the chromosphere. In previous studies, it has been indicated that the dissipation of generated shock waves can give enough thermal energy to heat the chromosphere. The effect of the magnetic diffusion to the nonlinear propagation of Alfvén waves in the chromosphere has not been investigated enough. Some observations show the reflection of Alfvén waves at the top boundary of the chromosphere, which is called the transition region. It is important to discuss the dissipation mechanisms of waves in consideration of the reflection mechanism at the top and bottom boundaries of the chromosphere.

In this study, we investigate the reflection of Alfvén waves propagating along a vertically open magnetic flux tube in the chromosphere at the transition region and photosphere. If we assume the atmospheric condition in the solar quiet region, the damping length of waves which have frequencies of 1–100 mHz by the magnetic diffusion is estimated to become much larger than the thickness of the chromosphere. For investigating the dissipation of Alfvén waves in the chromosphere, we should consider the condition where the reflection at the photosphere and transition region efficiently occurs and more Alfvén waves are trapped in the chromosphere. We investigate the propagations of the nonlinear Alfvén waves by performing one-dimensional numerical simulations. As a result, 60–70 % of the incident Alfvénic pulse waves with frequencies of 10–100 mHz are reflected at the transition region. Most of reflected waves from the transition region penetrate into the convection zone without being reflected at the bottom of the photosphere. We perform simulations in different magnetic field structures and confirm that the results are almost the same in any cases. It is considered to be important to take the energy flux going from the top and bottom boundaries of the chromosphere into account for the dissipation of Alfvén waves in the chromosphere. In the case where the initial velocity amplitude of Alfvén wave is set to be 1.0 km s^{-1}, the compressible waves generated by the nonlinear effect may have enough energy to heat the chromosphere. If the initial velocity amplitude is set to be smaller, less compressible waves are generated and other dissipation mechanisms of the Alfvén waves may become effective.

Keywords: chromospheric heating, Alfven wave, magnetic diffusion, nonlinear