Extrapolation of three-dimensional magnetic field structure in flare-productive active region with different initial condition

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Solar flares are known as explosive energy release events by magnetic reconnection in the solar atmosphere. To investigate what kind of processes contribute to the energy storage and trigger of solar flares, we need information of coronal three-dimensional magnetic field distribution. Although photospheric or chromospheric magnetic field can be obtained by spectropolarimetric observations, the examples of coronal magnetic field observations are very few due to its low polarimetric signal. As an alternative, nonlinear force-free field (NLFFF) extrapolation from the photosphere is a strong tool to infer the coronal magnetic field. However, previous studies report that there are some uncertainties in NLFFF calculation, such as method dependency, observational instrument dependency and spatial resolution dependency.

We investigate another possible uncertainty of the NLFFF calculation; the initial condition dependency. Three-dimensional magnetic field of flare-productive active region NOAA 11967 is investigated. We performed 12 NLFFF extrapolations with different initial conditions based on magnetohydrodynamics (MHD) relaxation method, which solves zero-beta MHD equations. MHD relaxation method begins with arbitrary initial three-dimensional magnetic field and the NLFFF solution is obtained by changing bottom boundary to the magnetic field observed in the photosphere. The initial conditions were set to be linear force-free field with different force-free alpha. We aim to reveal how the dependency of the NLFFF solutions on the initial condition affect the physical values, which are crucial for the understanding of the storage and trigger mechanism of solar flares. Total magnetic energy, magnetic free energy, and force-free alpha distribution of 12 different NLFFF solutions are presented.

We found that while force-free alpha distributions are quite similar among 12 NLFFF solutions in the lower height, those in the higher region are affected by the initial condition and tend to show different distributions. On the other hand, total magnetic energy and free energy show almost same values among 12 solutions. This result is due to the fact that large amount of the magnetic energy are distributed in the lower height. It implies that the total magnetic energy and free energy are independent of the choice of initial condition with MHD relaxation method. We also validated the NLFFF extrapolations by comparing between field lines of NLFFF results and soft X-ray image. We found that if we chose the appropriate initial condition, the sigmoidal structure in soft X-ray image can be reproduced.
In terms of space weather, our results provide the possibility of more accurate modeling of three-dimensional magnetic field in the solar corona by just choosing appropriate initial condition and enable us to discuss the necessary condition of the onset of solar flares with more realistic magnetic field distribution. On the other hand, our results also throw several questions: How is different between robust NLFFF solutions in the lower atmosphere and magnetic field observed in the chromosphere (lower atmosphere)? Which is more important for the onset of the flare, magnetic field in the lower atmosphere, which contains major part of the total energy, or large scale twisted field lines in the higher atmosphere,

which is usually seen in the flare-productive active region? The future observations and numerical modelings should answer these questions.

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