Geophysical Research Abstracts
Vol. 19, EGU2017-2310, 2017
EGU General Assembly 2017

Advances in solar flare science through modeling of the magnetic field in the solar atmosphere (Arne Richter Award for Outstanding ECSs Lecture)

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Ever since we know of the phenomenon of solar flares and coronal mass ejections, we try to unravel the secrets of the underlying physical processes. The magnetic field in the Sun's atmosphere is the driver of any solar activity. Therefore, the combined study of the surface (photosphere) magnetic field and the magnetic field in the atmosphere above (the chromosphere and corona) is essential. At present, direct measurements of the solar magnetic field are regularly available only for the solar surface, so that we have to rely on models to reconstruct the magnetic field in the corona. Corresponding model-based research on the magnetic field within flaring active regions is inevitable for the understanding of the key physical processes of flares and possibly associated mass ejections, as well as their time evolution.

I will focus on recent advances in the understanding of the magnetic processes in solar flares based on quasi-static force-free coronal magnetic field modeling. In particular, I will discuss aspects such as the structure (topology) of the coronal magnetic field, its flare-induced reconfiguration, as well as the associated modifications to the inherent magnetic energy and helicity. I will also discuss the potential and limitations of studies trying to cover the complete chain of action, i.e. to relate the (magnetic) properties of solar flares to that of the associated disturbances measured in-situ at Earth, as induced by flare-associated coronal mass ejections after passage of the interplanetary space separating Sun and Earth. Finally, I will discuss future prospects regarding model-based research of the coronal magnetic field in the course of flares, including possible implications for improved future flare forecasting attempts.