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Abstract. Two possibilities of plasma ejection from the Sun are considered: chromospheric evaporation due to a solar flare, and plasma acceleration along the current sheet during a solar flare. Results of numerical MHD simulation explain the association of flares and transients.

Introduction

Yohkoh x-ray measurements (*Tsuneta*, 1993, *Magara et al.*, 1996) demonstrate a plasma jet injection from the Sun after a two ribbons solar flare (SF). It has been shown that the SF of December 2, 1991 is accompanied by a powerful post flare loop (PFL), which have developed the vertical current sheet (CS). The plasma jet moves upward from the top of PFL. We present a scenario of jet ejection and vertical CS creation based on PFL appearance due to local chromospheric evaporation in the magnetic loop legs. Such local evaporation can be produced by precipitation of electrons accelerated at the solar flare and/or at chromospheric heating by the Pedersen currents. These Pedersen currents connect upward and downward field-aligned currents (FAC) which are generated at the SF by the Hall electric field.. The sketch of FAC generation (*Podgorny and Podgorny*, 1992) in the CS during a SF is shown in Fig. 1. PFL creation due to chromospheric evaporation has been demonstrated in (*Podgorny and Podgorny*, 1998a). The relative role of electron precipitation and Joule heating is different for different events.

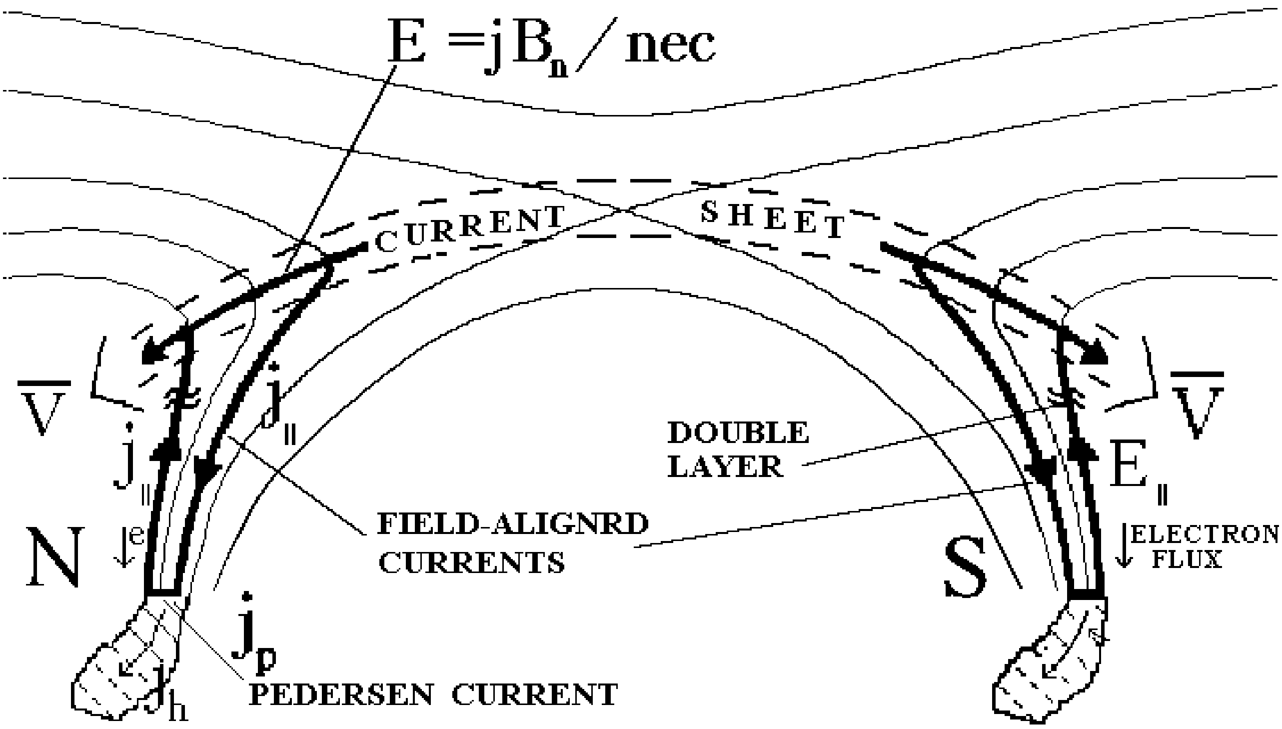

Fig. 1. The electrodynamical model of the solar flare. The circuit of field-aligned currents $j_{||}$ is shown.

Here we present briefly some results of MHD numerical simulation of the phenomena, which appear at powerful chromospheric evaporation in the active region after the SF, when energy stored in the CS disappears, and the potential magnetic field is restored. For calculations we use the field of four vertical dipoles with alternative polarity. In (*Podgorny and Podgorny*, 1992) it has been shown that the CS can be created in this field because of small photospheric disturbances, and the CS decay produces a SF.

There is another possibility for coronal mass ejection. It consists in plasma acceleration in the corona along the CS by the $\mathbf{j}\times\mathbf{B}/c$ force. The horizontal CS creation above an active region in magnetic field with a neutral, line and plasma acceleration has been demonstrated earlier (*Podgorny and Podgorny*, 1992). This effect is shown in Fig. 1. But for plasma ejection from the corona the vertical CS should appear. Here we demonstrate a possibility for the vertical CS creation, which ejects a plasma jet upward.

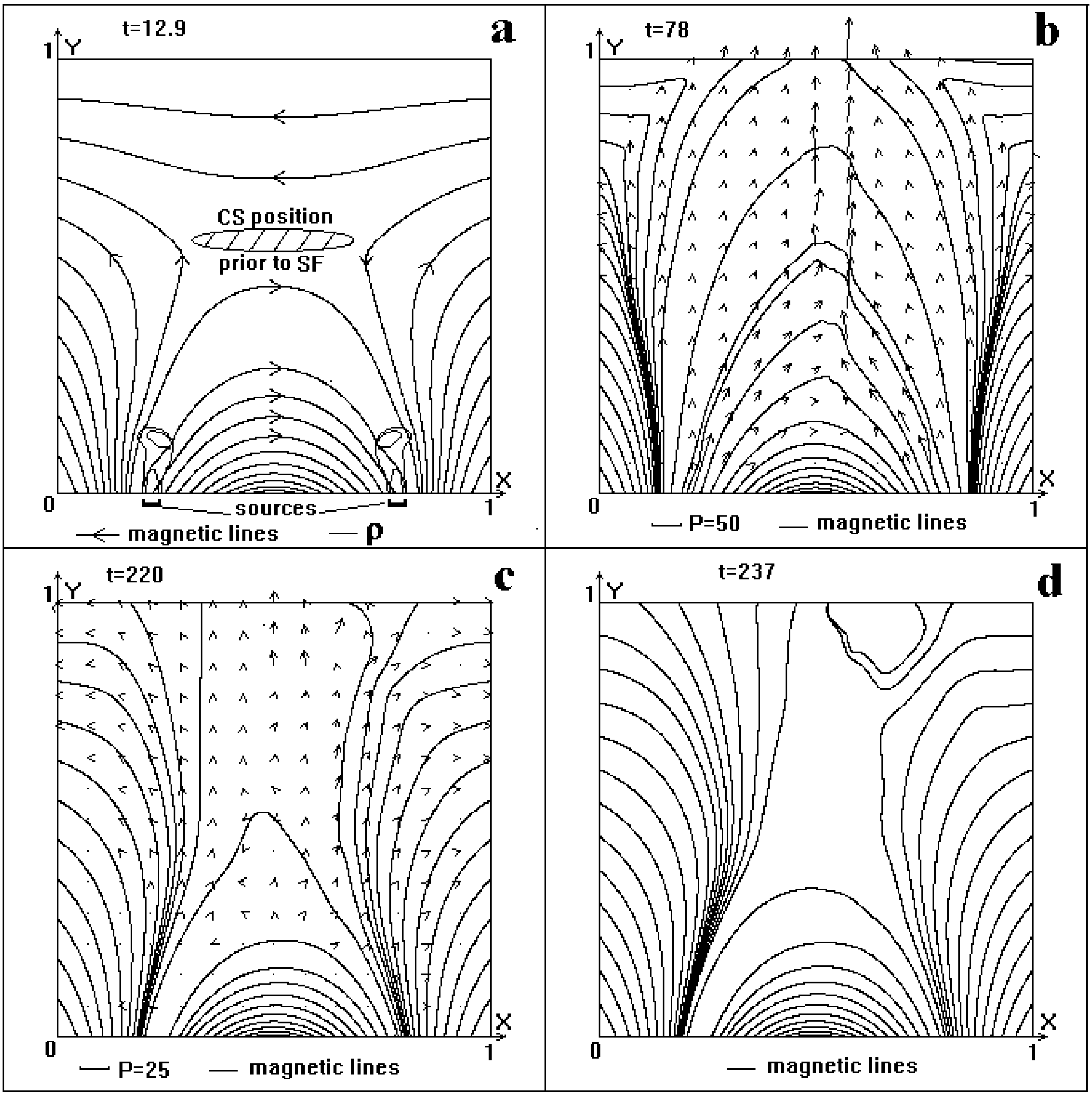

Fig. 2. Creation of CS and plasma ejection due to chromospheric evaporation. Magnetic lines and vectors of momentum are shown.

Ejection due to chromospheric evaporation

The PERESVET code is used for solving MHD equations with dissipative terms for compressible plasma. In previous calculations the net 61×61 has been used (*Podgorny and Podgorny*, 1999). Here we present some new results obtained with 121×121 net. The equations and method of calculation are described in (*Podgorny and Podgorny*, 1998a). The dimensionless parameters correspond to the principal of limited simulation (*Podgorny and Podgorny*, 1995): $\beta=2\times10^{-6}$, Reynolds number $Re=10^4$, magnetic Reynolds number $Re_m=2\times10^5$, and Peclet number $\Pi=\rho_0 L V_A/\kappa=100$, here κ is the thermal conductivity. Anisotropy of the thermal conductivity in the magnetic field is taken into account. The real magnetic Reynolds number is limited by the grid of the calculation region. The dimension of the numerical region L, the background plasma density ρ_o, the average photospheric magnetic field in the active region B_o, the Alfven velocity $V_A=B_o/(4\pi\rho_o)^{1/2}$, and the Alfvenic time L/V_A are units for length, plasma density, magnetic field, velocity, and time, respectively. For the active region with $L=10^{10}$cm and $V_A=5\times10^9$cm/c the dimensionless unit of time corresponds to ~2c. Long time calculation requires extreme care with setting the boundary conditions, which are changed during the calculations. For this purpose the linear equations are solved after the characteristics before every time step. As a result, invariants are obtained which permit determination of dependencies between plasma and field parameters on a boundary. This procedure permits us to set only a subset of values at the boundary, for example the magnetic field. The other parameters are obtained from invariants.

The plasma sources with $\rho=20000$ and T=20 are placed in photosphere in interval $0.2054\leq X\leq 0.2294$ and $0.7706\leq X\leq 0.7946$. At t=120 the sources are switched of, and $\rho=1$ and T=1 are set at all boundary Y=0.

The initial magnetic field configuration can be seen in Fig. 2a. Magnetic field directions are shown by arrows. At t= 13.9 magnetic field distortion is still not significant. Here lines of constant density are also presented. The positions of chromospheric local plasma sources are shown under X axis. The position of a CS which has been created prior to a SF and has been disappeared during this flare is also shown in Fig. 2a. The strong magnetic force directs the plasma flow at that time along the field lines. Later (t~30) plasma flow reaches regions of weak magnetic field, and magnetic field lines are stretched upward. The Fig. 2b shows magnetic field lines and vectors of momentum $\mathbf{P}=\rho\mathbf{V}$ at t=78. Here neutral point is displaced from the region. The strong rather narrow plasma jet moves upward from the numerical region. In Fig. 2c plasma jet almost ejected from the region. The magnetic lines shapes correspond to the magnetic field of a vertical CS. When the plasma jet leaves the numerical region CS stabilization due to plasma velocity is ceased. CS becomes unstable, and initial magnetic field is restored. Development of CS instability is seen in Fig. 2d. At that time the neutral point returns in the numerical region. This final phase of the phenomena is also simulated in (*Yokoyama and Shibata*, 1998) for the CS without the normal magnetic field component.

A jet ejection from the CS

For consideration of plasma acceleration in a vertical CS the 3D Peresvet code version is used. Calculations are performed for the preflare active region AR NOAA 6654 of 30 May 1991. For approximation of the initial field the values and positions of four dipoles are selected (*Podgorny and Podgorny*, 1998b). In Fig. 3a the magnetic field configuration is shown in the plane perpendicular to the photosphere in which dipoles are placed. CS creation has been investigated for photospheric disturbances made by changing in time values and position of dipoles. The energy accumulated in the magnetic field is released at the CS decay, and a solar flare occurs. At that time plasma acceleration along the CS takes place. CS inclination to the photosphere depends on the mode of photospheric disturbances. The case with vertical CS is seen in Fig. 3b, where vectors of $\rho\mathbf{V}$ and magnetic lines are presented. The force $\mathbf{j}\times\mathbf{B}/c$ above the neutral line accelerates plasma jet upward producing solar mass ejection. The ejection velocity exceeds the local Alfven one.

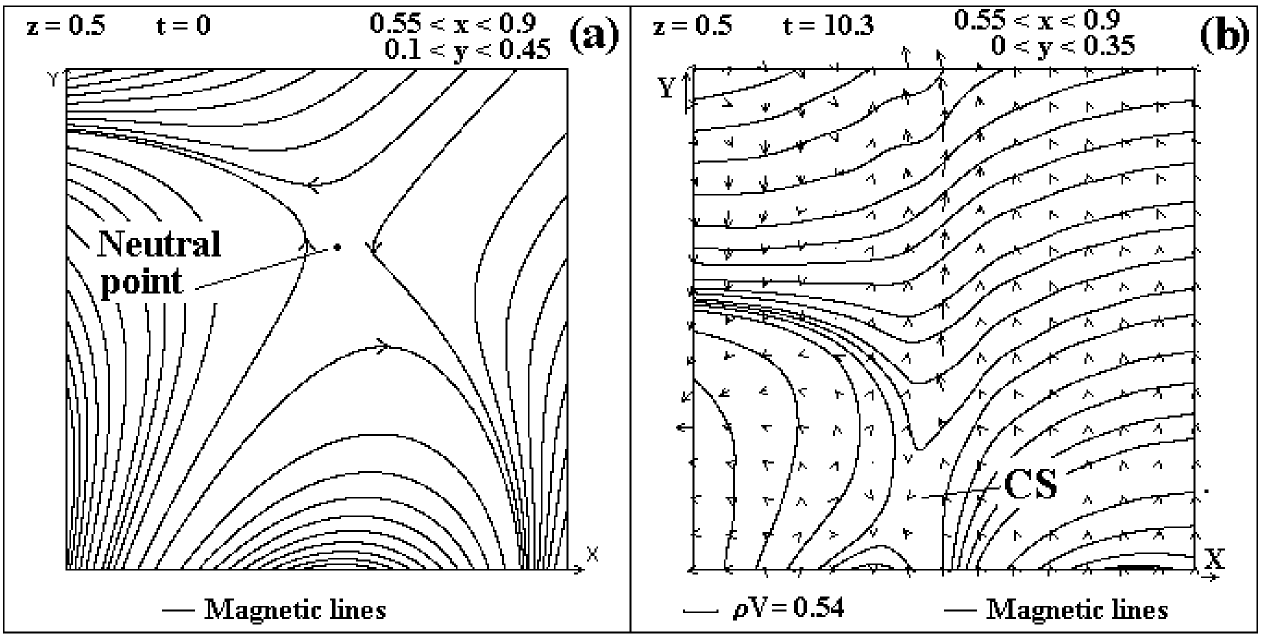

Fig. 3. The vertical CS creation above the real active region. (a)The initial magnetic field configuration above the real active region. (b) Plasma jet ejection from the vertical CS creation.

Conclusion

The results of MHD numerical simulation demonstrate the possibility of transient creation by plasma acceleration in the vertical CS and by chromospheric evaporation due to local chromospheric heating during a solar flare. These results explain numerous observation of solar flares and transients appearance (Dryer M. *et al.,* 1998).

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