Long-Term Datasets for the Understanding of Solar and Stellar Magnetic Cycles
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A Magnetofrictional model for the solar corona

Soumyaranjan Dash[1,a] **and Dibyendu Nandy**[1,2,b]

[1]Center of Excellence in Space Sciences India,
Indian Institute of Science Education and Research Kolkata, Mohanpur 741246, India
[2]Department of Physical Sciences,
Indian Institute of Science Education and Research Kolkata, Mohanpur 741246, India
email: [a]`sd16rs002@iiserkol.ac.in`, [b]`dnandi@iiserkol.ac.in`

Abstract. Regular reconstruction of global solar corona constrained by observational data is required to monitor the space weather variations. We develop a model for simulating the global coronal magnetic field using magnetofrictional approach. Here we perform simulations to study the evolution of the magnetic field associated with a bipolar active region in response to photospheric flows.

Keywords. Sun: corona, Sun: evolution

1. Introduction

Understanding the dynamics of space weather requires a critical insight of the solar coronal magnetic field and its evolution. For explaining the coronal evolution [Yeates *et al.* (2010)], we depend on observationally driven theoretical models. A detailed description of these theoretical models can be found in Mackay *et al.* (2012). One of the extrapolation techniques is based on magnetofrictional (hereafter MF) approach [(Yang *et al.* (1986) and Craig *et al.* (1986))]. This model, assumes that the inductive velocity is proportional to the Lorentz force for the relaxation of magnetic field towards a stress-free condition. Here we have explained our model setup and described the evolution of a bipolar active region in the following sections.

2. Method

Our model is principally based on the MF scheme used by van Ballegooijen *et al.* (2000). Plasma velocity ($\mathbf{v}$) is proportional to the Lorentz force $\mathbf{F} = \frac{1}{4\pi}\mathbf{j}\times\mathbf{B}$ everywhere, where current density is defined by $\mathbf{j} = \nabla\times\mathbf{B}$. Magnetic field ($\mathbf{B}$) is evolved by the magnetohydrodynamic (MHD) induction equation. Under ideal MF evolution, important topological quantities remain conserved. The ohmic diffusion accommodates the scope for reconnection and thereby restructuring of magnetic fields at the locations where current sheets are formed.

To ensure that the divergence-free condition is consistent with the evolution of the field, we choose to model the MHD induction equation in terms of magnetic vector potential ($\mathbf{A}$), which is given by,

$$\frac{\partial\mathbf{A}}{\partial t} = \mathbf{v}\times\mathbf{B} - \eta_c\mathbf{j} \tag{2.1}$$

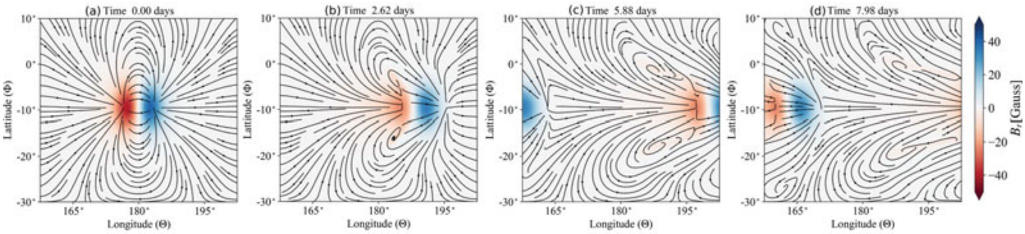

Figure 1. This image shows the stress-free configuration of the representative active region (a) and Evolution of the magnetic field associated with the active region after 2.62 days (b), 5.88 days (c) and 7.98 days (d).

With the magnetofrictional coefficient (ν), the velocity and diffusivity are defined as,

$$\mathbf{v} = \frac{1}{\nu}\frac{\mathbf{j}\times\mathbf{B}}{B^2} + v_0 e^{-(2.5R_\odot\ -r)/r_w}\,\widehat{\mathbf{r}}, \eta_c = \eta_0\left(1 + 0.2\frac{|\mathbf{j}|}{|\mathbf{B}|}\right) \tag{2.2}$$

The second term in the velocity profile (2.2) mimics the effect of solar wind beyond the source surface. The coronal diffusivity profile (η_c) is inspired from Yeates *et al.* (2007).

Here we study the evolution of a representative bipolar active region on a spherical grid, ranging from $R_\odot \leqslant r \leqslant 2.5R_\odot$, $60° \leqslant \theta \leqslant 100°$, and $150° \leqslant \phi \leqslant 210°$ with a uniform grid resolution of $dr = 0.015R_\odot$, $d\theta = 0.33°$ and $d\phi = 0.33°$.

3. Result and Discussion

Integrating the model forward results in a force-free state of the magnetic fields. We apply a constant longitudinal velocity to observe the field evolution. As the longitudinal boundary is periodic, we expect the active region to appear again inside the domain. Figure 1 shows the evolution of the magnetic fields in response to the imposed photospheric flow. Energy is transported from the photosphere into the low-β corona which drives reconnections at the locations of current-sheet which causes eruptive events like flares and coronal mass ejections. We aim to simulate the global corona driven by photospheric magnetic field infromation in future.

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