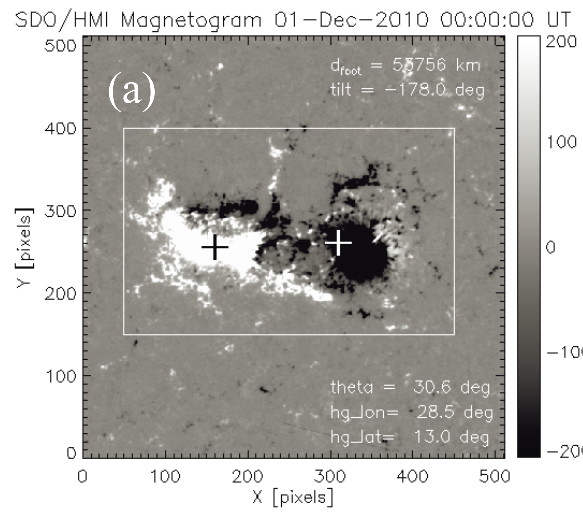
Statistical Analysis of the Horizontal Divergent Flow in Emerging Solar Active Regions

TORIUMI, Shin (NAOJ)
HAYASHI, Keiji (Stanford University)
YOKOYAMA, Takaaki (The University of Tokyo)

It is widely accepted that the formation of active regions of the Sun is caused by emerging magnetic fields from the convection zone [1]. In the previous MHD simulation studies (e.g., [2]), we pointed out that the emerging magnetic fields push up the local (non-magnetized) plasma above their heads. It is therefore expected that the horizontal divergent flow (HDF) appears before the magnetic flux itself emerges at the visible surface of the Sun. In fact, the HDF was observationally detected in a flux emergence event we selected [3]. In this work [4], we analyzed the HDFs in many more flux emergence events and investigated the physical state of the subsurface magnetic fields, which we cannot directly observe.

We analyzed flux emergence events that were observed by the Helioseismic and Magnetic Imager (HMI) on board the Solar Dynamics Observatory (SDO). We searched for the events that appeared in the eastern hemisphere with a heliocentric angle $\theta \leq 60°$ during the period between 2010 May and 2011 June (14 months) and picked up 23 events. Figure 1(a) is a sample of the events, showing the line-of-sight magnetic field.

Out of the 23 events, 6 clear HDFs were detected by the method previously developed in [3], while 7 additional events that were detected by visual inspection were added to this statistic analysis. The distribution of the events is shown in Figure 1(b). From this map, one may find that the flux emergence events are distributed in the mid-latitude bands of both hemisphere and that the clear HDFs are concentrated in the area with a heliocentric angle $\theta > 30°$. As a result of the statistical analysis, we found that the duration of the HDF is on average 61 minutes and the maximum HDF speed is on average 3.1 km s^{-1}. We also estimated the rising speed of the subsurface magnetic fields to be 0.6–1.4 km s^{-1}. These values are consistent with the previous one-event analysis [3] as well as the numerical simulation results [2].



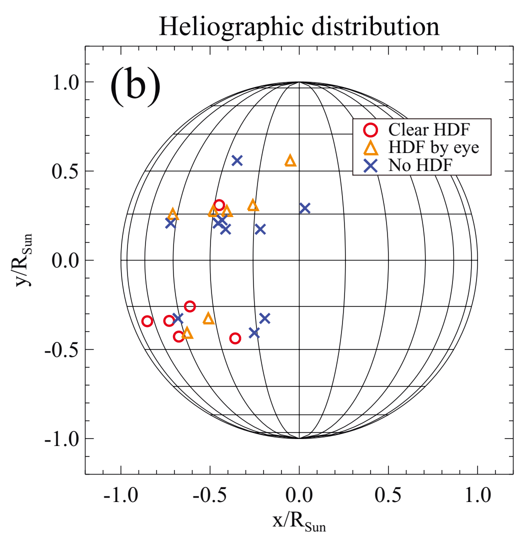


Figure 1: (a) Example of flux emergence data showing line-of-sight magnetic field strength. The black and white plus signs are the flux-weighted centers of positive and negative polarities, respectively, measured in the rectangular box. 1 pixel corresponds to 0.5 arcsec. (b) Heliographic distribution of the flux emergence events. Figures reproduced from [4].

References

[1] Parker, E. N.: 1955, *ApJ*, **121**, 491.
[2] Toriumi, S., Yokoyama, T.: 2013, *A&A*, **553**, A55.
[3] Toriumi, S., et al.: 2012, *ApJ*, **751**, 154.
[4] Toriumi, S., et al.: 2014, *ApJ*, **794**, 19.