Long-Term Datasets for the Understanding of Solar and Stellar Magnetic Cycles
Proceedings IAU Symposium No. 340, 2018
D. Banerjee, J. Jiang, K. Kusano & S. Solanki, eds.

doi:10.1017/S1743921318001370

Studying solar-cycle variation of open magnetic flux regions using coronal holes

Chia-Hsien Lin[1], **Guan-Han Huang**[1] **and Lou-Chuang Lee**[2]

[1]Graduate Institute of Space Science,
National Central University, Taiwan
email: chlin@jupiter.ss.ncu.edu.tw
[2]Institute of Earth Sciences, Academia Sinica, Taiwan
email: louclee@earth.sinica.edu.tw

Abstract. The process of the magnetic polarity reversal of the Sun has been an important subject in the solar physics. The objective of this study is to investigate how solar global magnetic field change over solar cycle by tracking the migration of open magnetic flux regions. The results show that the open magnetic fluxes migrate from one pole to the other crossing the equator during a solar cycle. The migration rate is approximately 10 m s^{-1}, comparable to meridional flow. The results have been published in Scientific Reports (Huang *et al.* (2017)).

Keywords. Sun: magnetic fields, Sun: solar wind, Sun: activity, Sun: corona

1. Introduction

Coronal holes can be defined as regions in which magnetic field lines extend far away from the Sun into interplanetary space (Obridko & Shelting(1999)), in other words, regions with open magnetic flux (OMF). Their magnetic field structure is part of the largest-scale solar magnetic field. The objective of this study is to trace the migration of OMF regions over solar cycles to unveil the process of solar polarity reversal.

2. Method

To identify OMF regions, we used the synoptic maps of Wilcox Solar Observatory radial magnetic fields from May 1976 to December 2014 (Carrington Rotation number 1642 to 2158), and applied Potential Field Source Surface (PFSS) extrapolation procedure (Schatten *et al.*(1969)) to construct the 3D magnetic field from 1 to $2.5R_\odot$. All field lines at $2.5R_\odot$ are set to be radial. After the 3D magnetic field is constructed, the field lines were traced from $2.5R_\odot$ down to solar surface. The footpoints of the open field lines are identified as OMF regions. Each OMF region is specified by longitude (ϕ), latitude (λ) and Carrington Rotation (i.e., time t). To study how OMF regions change as a function of t and λ, we constructed time maps of unsigned, outward, and inward OMF area by summing the area of unsigned, outward, and inward OMF over ϕ at each t. The results are denoted as $\Psi_{\mathrm{OMF}}(\lambda, t)$, $\Psi_+(\lambda, t)$, and $\Psi_-(\lambda, t)$, respectively, and are plotted in Figure 1(a) to Figure 1(c). To enhance the visibility of the patterns, the plotted values are $\sqrt{\Psi_{\mathrm{OMF}}}$, $\sqrt{\Psi_+}$, and $\sqrt{\Psi_-}$.

3. Result and Discussion

Figure 1(a) shows that OMF area at the two poles are approximately symmetric with each other, except for the last cycle when the OMF area is larger in the south pole than in the north pole. Figure 1(b) and 1(c) indicate that the OMF regions of same

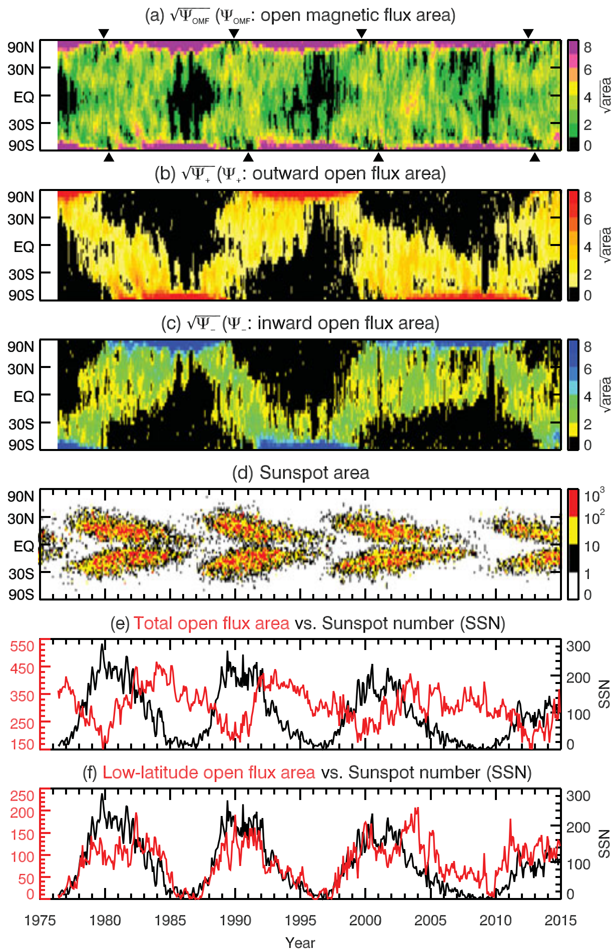

Figure 1. Time maps of unsigned, outward and inward open flux area are placed in (a)–(c). The sunspot butterfly diagram is plotted in (d). The sunspot number (SSN) and the total open flux area of all latitude as functions of time are compared in (e). The comparison between SSN and low-latitude open flux area is shown in (f). *(reproduced from Huang et al. (2017))*

polarity perform a pole-to-pole trans-equatorial (PPTE) migration over a solar cycle with a migration rate of $\approx 26.7 \pm 6.4$ deg/year (10.3 ± 2.5 m s^{-1}). This is in contrast to the migration of sunspots, which typically starts from approximately 35° toward equator, as shown in the sunspot butterfly diagram in Figure 1(d). In Figure 1(e), the black line is the sunspot number (SSN) as a function of time, and the red line is $\Psi_{\rm OMF}$ summed over all latitudes. The comparison shows that SSN is negatively correlated with $\Psi_{\rm OMF}(t)$, that is, total open flux area peaks approximately at the time when SSN is minimum, and *vice versa*. In contrast, a positive correlation is found between SSN and the open flux area in the low latitude ($|\lambda| \leqslant 30°$), as revealed in Figure 1(f).

References

Huang, G.-H., Lin, C.-H., & Lee, L. C. 2017, *Scientific Reports*, 7, 9488

Obridko, V. N. & Shelting, B. D. 1999, *Solar Physics*, 187, 185

Schatten, K. H., Wilcox, M. M., & Ness, N. F. 1969, *Solar Physics*, 6, 442

https://doi.org/10.1017/S1743921318001370 Published online by Cambridge University Press