Long-Term Datasets for the Understanding of Solar and Stellar Magnetic Cycles
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A prediction of the solar cycle 25

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Abstract. Here we report our recent prediction of the solar cycle 25 based on a newly developed scheme, which is used to investigate the predictability of the solar cycle over one cycle. The scheme is a combination of the empirical properties of solar cycles and a surface flux transport model to get the possible axial dipole moment evolution at a few years before cycle minimum, by which to get the subsequent cycle strength based on the correlation between the axial dipole moment at cycle minimum and the subsequent cycle strength. We apply this scheme to predict the large-scale field evolution since 2018 onwards. The results show that the northern polar field will keep on increasing, while the southern polar field almost keeps flat by the end of cycle 24. This leads to the cycle 25 strength of 125 ± 32, which is about 10% stronger than cycle 24 according to the mean value.

Keywords. Sun: activity, Sun: evolution, Sun: magnetic fields, (Sun:) sunspots

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There are two distinctive features about the shape of the solar cycle. One is that stronger cycles tend to show a faster rise of activity levels during their ascending phase than weaker cycles. This is so-called Waldmeier effect. This effect was well incorporated in the profile of the solar cycle suggested by Hathaway *et al.* (1994). The second is that once the solar cycle begins to decline, all cycles decline in a similar way, but with certain scatter comparing with the means over all the cycles. This feature was not generally recognized during the past studies. It also depends on the definition of the declining phase, see Table 1 of Hazra *et al.* (2015) for the difference. We statistically analyzed the shapes of solar cycles 12-24. The results show that when a cycle starts for more than 4 years, the possible sunspot group emergence during the rest time of an ongoing cycle can be predicted by a set of random realizations, which obey the statistical relations.

Jiang *et al.* (2007) show that the polar field at cycle minimum has a good correlation with the subsequent cycle strength. The random features of sunspot emergence, especially the sunspot tilts, have significant effects on the polar field generation. Hence they put constraints on the scope of accurate solar cycle prediction (Jiang *et al.* 2014; Jiang *et al.* 2015). We use a surface flux transport model to get the possible axial dipole moment evolution. The random sunspot emergences provide the source of magnetic flux and the observed synoptic magnetogram is used as the initial condition. The correlation between the axial dipole moment at cycle minimum and the subsequent cycle strength constrained by observed long-term magnetograms is used to give the possible strength and the profile of the subsequent cycle.

We apply this scheme to predict the large-scale field evolution since 2018 onwards. The results are shown in Figure 1. The mean axial dipole moment will slightly increase. Northern polar field will keep on increasing, while the southern polar field will almost keep flat by the end of cycle 24. These are caused by strong poleward positive plumes starting from second half of 2017. The positive plume in the northern hemisphere will further increase the positive polar field. The positive plume in the southern hemisphere

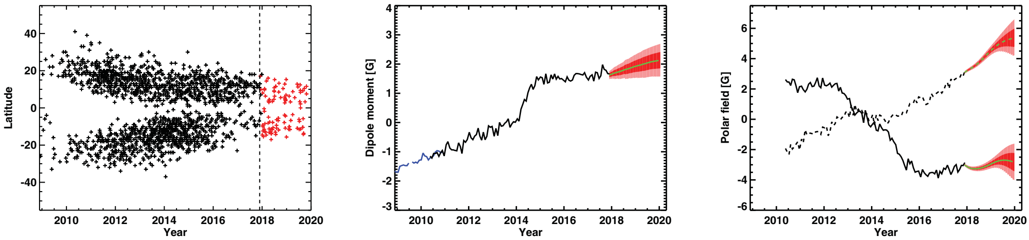

Figure 1. Prediction of the large-scale field evolution over the solar surface during the rest of the ongoing cycle 24 using the HMI synoptic magnetogram CR2198 as the initial field. Left panel: the butterfly diagram. The observed sunspot groups are in black and the predicted spots by one random realization are in red. Middle panel: Axial dipole field evolution; Right panel: polar field evolution, north polar field in dashed curve and south polar field in solid curve. The green curves are the averaged values of 50 random realizations. The light and dark red shade regions correspond to σ and 2σ uncertainty ranges.

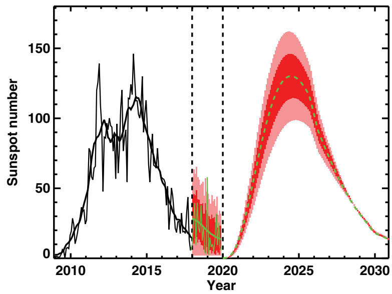

Figure 2. Predictability of the solar cycle 25 using the HMI synoptic magnetogram CR2198 as the initial condition. The dark and light red shading areas indicate the total σ and 2σ uncertainty range. The thick green curve are the mean predictions. The thin green curve shows the one random realization of the prediction during the rest of the ongoing cycle.

will prevent the increase of southern negative polar field. Hence it keeps almost stable. The possible evolution of the smoothed sunspot number until the end of cycle 25 based on the statistical relations of solar cycles and the possible axial dipole moments at the end of cycle 24 is given in Figure 2. The expected maximum amplitude of cycle 25 is 124, which is about 10% higher than current cycle 24. The 2σ range is 32, which means that the possibility of the amplitude of cycle 25 above 92 is 95%. Cycle 25 most probably is a normal cycle, rather than the Maunder minimum period. The scheme is an extension of the methods used by Cameron *et al.* (2016). More details about the scheme and its validity will be submitted to a referred journal soon.

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