How the Statistical Analysis of Magnetic Structures Will Help Us Usher a New Generation of Solar Cycle Predictions

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Due to its clear modulation of solar activity, the solar cycle is the main driver behind changes in the heliospheric environment, and the Earth's magnetosphere and atmosphere. For this reason, long-term prediction of activity levels has been one of the main practical goals of solar physics. During the last three solar cycles, there have been many attempts to predict the amplitude of the solar cycle with different degrees of success. One of the clear lessons, learned from the last round of cycle amplitude predictions, is the confirmation that the polar magnetic fields are the best cycle amplitude precursor (once solar minimum has been reached). With this in mind, it is clear that the scope of solar cycle predictions has to expand beyond simply predicting amplitude, in order to improve their timeliness, usefulness, and accuracy.

Ultimately, both the causal propagation of the solar cycle, and the modulation of solar activity and heliospheric conditions, are tied to the emergence and decay of bipolar magnetic regions (BMRs) on the photosphere. For this reason, it is necessary to gain an intimate understanding of their properties and how are they connected to the evolution of the cycle itself. Here we show the results of analyzing data taken by 10 different observatories, discuss what they teach us about the systematic evolution of BMR tilt and flux, and demonstrate how this can be used to improve solar cycle prediction.