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Algebraic quantification of an active region contribution to the solar cycle

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The solar dipole moment at cycle minimum is considered to be the most reliable precursor to determine the amplitude of the subsequent cycle. Numerical simulations of the surface flux transport (SFT) model are widely used to effectively predict the dipole moment. An algebraic method was recently proposed to quickly predict the contribution of an active region (AR) to the axial dipole moment at cycle minimum instead of SFT simulations. The method assumes a bipolar magnetic region (BMR) configuration of ARs, however most ARs are asymmetric in configuration of opposite polarities, or have more complex configurations. Such ARs evolve significantly differently from those of BMR approximations. We propose a generalized algebraic method to describe the axial dipole contribution of an AR with an arbitrary configuration, and evaluate its effectiveness compared to the BMR-based method by comparing its results with SFT simulations of observed ARs and artificial ARs. We also compare the results with those from the BMR-based method. The generalized method is equivalent to the SFT model, and precisely predicts the contributions of ARs to the dipole moment, but has a much higher computational efficiency. Although the BMR-based method has similar computational efficiency to the generalized method, it is only accurate for symmetric bipolar ARs. The BMR-based method systematically overestimates the dipole contributions of asymmetric bipolar ARs, and randomly miscalculates the contributions of more complex ARs. The generalized method quick and precisely quantifies an AR's contribution to solar cycle evolution, which paves the way for application in physics-based solar cycle predictions.

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