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Solar Activity Modeling: from Subgranular Dynamical Scales to the Solar Cycles

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Dynamical effects of solar magnetoconvection span a wide range spatial and temporal scales that extends from the interior to the corona and from fast turbulent motions to the global-Sun magnetic activity. To study the solar activity on short temporal scales (from minutes to hours), we use 3D radiative MHD simulations that allow us to investigate complex turbulent interactions that drive various phenomena, such as plasma eruptions, spontaneous formation of magnetic structures, funnel-like structures and magnetic loops in the corona, and others. In particular, we focus on multi-scale processes of energy exchange across the different layers, which contribute to the corona heating and eruptive dynamics, as well as interlinks between different layers of the solar interior and atmosphere.

For modeling the global-scale activity we use the data assimilation approach that has demonstrated great potential for building reliable long-term forecasts of solar activity. In particular, it has been shown that the Ensemble Kalman Filter (EnKF) method applied to the Parker-Kleeorin-Ruzmakin dynamo model is capable of predicting solar activity up to one sunspot cycle ahead in time, as well as estimating the properties of the next cycle a few years before it begins. In this presentation, using the available magnetogram data, we discuss development of the methodology and forecast quality criteria (including forecast uncertainties and sources of errors). We demonstrate the influence of observational limitation on the prediction accuracy. We present the EnKF predictions of the upcoming Solar Cycle 25 based on both the sunspot number series and observed magnetic fields, and discuss the uncertainties and potential of the data assimilation approach for modeling and forecasting the solar activity.