Physics-Based Approach to Predict the Solar Activity Cycles
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Observations of the complex highly non-linear dynamics of global turbulent flows and magnetic fields are currently available only from Earth-side observations. Recent progress in helioseismology has provided us some additional information about the subsurface dynamics, but its relation to the magnetic field evolution is not yet understood. These limitations cause uncertainties that are difficult to take into account, and perform proper calibration of dynamo models. The current dynamo models have also uncertainties due to the complicated turbulent physics of magnetic field generation, transport and dissipation. Because of the uncertainties in both observations and theory, the data assimilation approach is natural way for the solar cycle prediction and estimating uncertainties of this prediction. I will discuss the prediction results for the upcoming Solar Cycle 25 and their uncertainties and affect of Ensemble Kalman Filter parameters to resulting predictions.

Data Assimilation Methodology

Test predictions of Solar Cycles 25 (top row) and 19 (bottom) reveal influence of the number of ensemble members on ability of the dynamo model to predict future activity cycles.

Uncertainties in Prediction of the Solar Cycle 25

Conclusions

Predicting solar cycles is one of most remaining problems closely linked to dynamo processes inside the Sun. The difficulty is due to our incomplete understanding of the physical mechanisms of the solar dynamo and also due to observational limitations that result in significant uncertainties in the initial conditions and model parameters. We have developed a relatively simple non-linear mean-field dynamo model, which nevertheless can describe essential dynamo properties of the cycles and the observed a.mplitude time series (such as Wilmott’s rule). Combined with the data assimilation approach, this model provides reasonable estimates for the strength of the following solar cycles. In particular, the prediction of Cycle 25 is calculated and published in 2018 with much more details than in the past. It was found that the best periods for predicting the future solar cycles are during the preceding solar minimum or solar maximum. This effect is explained by the fact that the magnetic field at the solar surface is affected by the underlying processes in the Sun for longer times. The exact time of the polar field reversals can significantly change their polarity. During these periods the uncertainty of predictions is decreased because the model ensemble primarily depends only on one of the field components. However, the prediction of Cycle 25 is reduced when the polarity reversals are not simultaneous and occurs in the Northern and Southern hemispheres with some delay. This means that the current dynamo theories are not able to model the hemispheric asymmetries. This finding was unexpected, and will require further investigation. Using the current observational data, prediction and prediction uncertainty have been calculated for Solar Cycle 25. The updated prediction of Cycle 25 shows that this cycle will start in about 2021 reach the maximum in 2024 - 2025, and the mean sunspot number at the maximum will be about 90 (for the v2.0 model ensemble primarily depends only on one of the field components. However, the accuracy of the