Project Details

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Project Title:
Predicting Global-Scale Solar-Cycle Features using a Flux-transport Dynamo Model

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Summary:
Understanding solar cycle mechanisms and predicting the features of an upcoming cycle have become an increasingly necessary and challenging task for our technological society. In the past, the so-called "precursor method" predicted some cycles well, but not the current cycle 23, which has behaved anomalously (de Toma et al. 2004). Following the postulate of previous authors (Schatten et al. 1978) that there is "magnetic persistence" or a memory of past magnetic fields in the Sun, and demonstrating the physical origins of such a memory in a flux-transport dynamo model of the solar cycle, we (Dikpati et al. 2004) recently built the first physical model for large-scale solar cycle prediction. Dikpati et al. (2004) have been able to show why solar cycle 23 behaved anomalously, and therefore why its features were not accurately predicted. By incorporating observed dynamical variations of the dynamo ingredients, namely the surface poloidal field source and the meridional circulation, we showed that a 10-20% weakening of the large-scale, surface poloidal field source in cycle 23 relative to the previous cycle 22 was the primary reason for a major delay in the polar reversal of cycle 23. Helioseismic observations indicate that the meridional flow decreased systematically during 1996-2002 and it remained slow until March 2004. We are now showing that this systematic decrease in the meridional flow speed caused the unusually slow rise of cycle 23. We are also making preliminary predictions (Dikpati et al. 2004b) that the onset of the upcoming cycle 24 should be delayed, starting late in 2007 or early in 2008. Here we propose research aimed at predicting the large-scale, mean solar cycle features, by further exploitation of our model using observed time-variations in various dynamo ingredients. We will focus on the solar cycle time-scale and predict the timings and amplitudes of upcoming cycles; the timing depends mostly on the meridional flow while the amplitude mostly on the Sun's memory effect. In order to do realistic predictions, we need to incorporate observations, namely the observational data from GONG, MWO, SOHO MDI and SDO HMI for the meridional flow and the NSO/Kitt Peak data for the surface source for weak magnetic fields that would determine the polar reversal and the amplitude of the future cycles. We will analyze the correlations between the dynamo-generated magnetic flux in the shear layer and the surface magnetic flux, spot area and spot number using data from wwwssl.msfc.nasa.gov/ssl/pad/solar/greenwch.htm -- such correlations should give us insight about the processes that determine the surface manifestations of the dynamo-generated flux. By analyzing the rise and fall patterns of each past cycle, we can construct, by using the Dikpati \& Charbonneau (1999) scaling law, a plausible meridional flow speed variation over the past 12 cycles. By postulating plausible relations between the differential rotation in the tachocline and the strength of the toroidal field induced and stored there, we will then attempt to simulate and explain Maunder minimum as well as Medieval maximum type behaviour. If successful, this effort could also help explain solar variability on a time-scale of centuries.

Publication References:

Summary: no summary

Reference: Dikpati, M.; (2005), Solar magnetic fields and the dynamo theory, Advances in Space Research, Volume 35, Issue 3, p. 322-328, doi: 10.1016/j.asr.2005.04.061

Summary: no summary

Reference: Dikpati, Mausumi; Gilman, Peter A.; (2006), Simulating and Predicting Solar Cycles Using a Flux-Transport Dynamo, The Astrophysical Journal, Volume 649, Issue 1, pp. 498-514, doi: 10.1086/506314