(Form02-2)

To constrain the physics of the origin of Maunder Minimum with historical archival records

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1. Summary

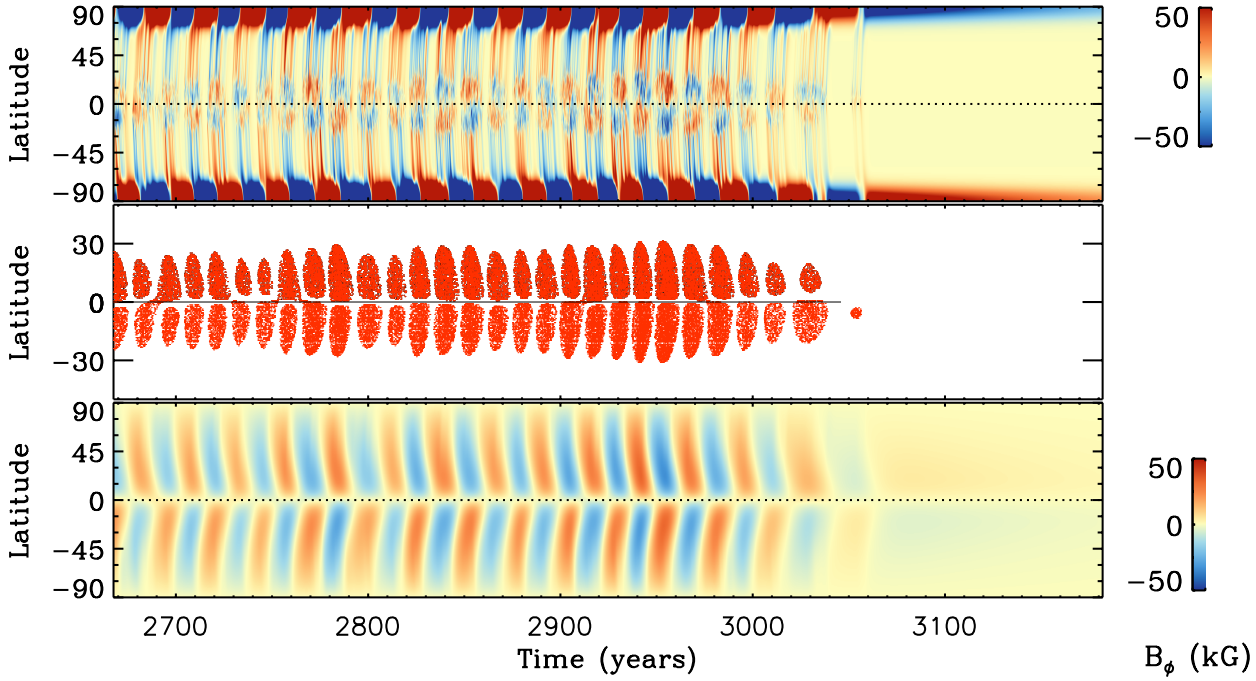
The Sun's magnetic activity follows a prominent 11-year cycle, visible through sunspots and magnetic field measurements. However, historical records show that there have been periods when activity dropped drastically. The popular example of these is the Maunder Minimum. Fluctuations in the properties of active regions (Bipolar Magnetic Regions) are believed to be the cause of these events, as demonstrated through dynamo simulations. However, how the Sun recovers from such event is an important subject of research. We have attempted this problem by considering the small active regions such as ephemeral regions into our dynamo model and exploring their recovery.

2. Purpose

To investigate whether the Babcock–Leighton dynamo alone can explain recovery from grand minima or if additional mechanisms are required.

3. Methodology

We empty the 3D kinematic dynamo code (Karak & Miesch ApJ 2017), STABLE in which the generation of poloidal field is captured by realistic sunspot properties. The fluctuations in the tilt angle is taken from observed distribution. The large-scale flow is taken from observations.



Caption: Top: Radial magnetic field on the surface of the Sun, middle: Locations of sunspots, bottom: Toroidal magnetic field at the base of the convection zone. All are plotted as function of latitude and time.

4. Results

We simulate the solar cycle using the model described above for several thousands of years. We find irregular variation in the solar cycle including frequent grand minima. We find that the grand minima arise due to random tilt variations in sunspots. A significant number of sunspots still exist during minima and help sustain the cycle. However when the sunspot disappear for a few years, the model fail to recover from the phase as shown in the figure. Currently we are conducting simulations at different parameter regions and trying at what condition the model recovers from the grand minima. Due to limitations of the computing resources, the project was not completed in scheduled time, however, we are working on it and we expect to complete it soon.

5. Period of stay in ISEE

27 — 29 September, 2025