Historical evolution of the geomagnetic field

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The evolution of the ancient geomagnetic field can be reconstructed from historical man-made measurements as well as from the magnetization acquired by geological and archeological archives. The historical field model BIGMUDIh.1 combines these two different data types revealing a 6% decrease of the global geomagnetic field strength between 1500 and 1600 CE, similar to the currently observed dipole decline.

Studying past geomagnetic field variations is important for understanding the dynamics of planetary magnetic fields that shield the biosphere and technical infrastructure against energetic cosmic particles and to constrain possible geodynamo mechanisms in the Earth's outer core and radionuclide production within the atmosphere.

Despite efforts to provide continuous paleomagnetic field reconstructions on longer timescales, the evolution of the axial dipole over more recent epochs is still uncertain (Fig. 1). Therefore, a temporally continuous spherical harmonic model (BIGMUDIh.1) covering the period of historical geomagnetic measurements has been constructed (Arneitz et al., 2021, https://doi.org/10.1029/2021JB022565). Because (direct) historical records comprise mainly declination observations due to navigational purposes, (indirect) field intensity estimates derived from archeo- and paleomagnetic measurements are crucial to constrain the dipole evolution over the last six centuries. Different laboratory techniques are applied to investigate the magnetization of rocks and archeological artifacts. This leads to a strongly heterogeneous data quality. The quality of indirect intensity records is taken into account within the bootstrapping approach by giving more weight to data obtained from high-quality experiments.

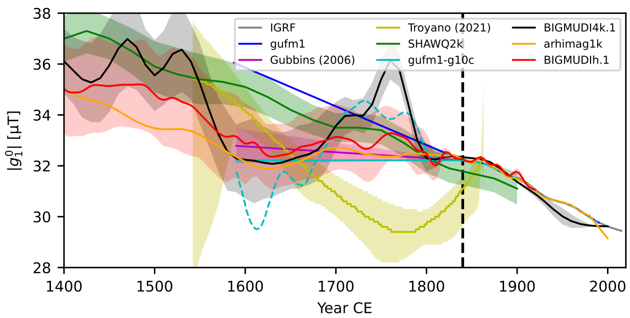

Figure 1: Temporal evolution of the axial dipole coefficient g_0^1 over the historical period given by different models.

The historical evolution of the axial dipole (g_0^1) is characterized by a significant decrease of $\sim 6\%$ in the 16th century, followed by a relatively stable period until the 19th century (Fig. 1, red line). From 1900 onwards systematic observatory observations of the geomagnetic field have revealed a de novo decrease of g_0^1 until today.

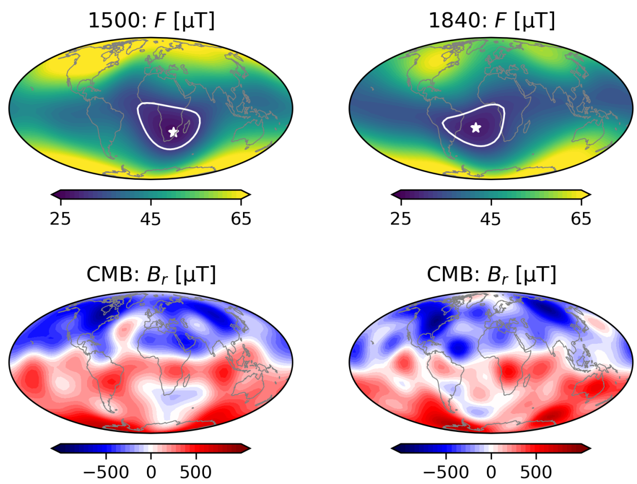

Figure 2: Evolution of the SAA from 1500 CE (left) to 1840 CE (right) at the Earth's surface (top). It is connected to RFPs at the CMB (bottom).

Not only global field characteristics, but also the evolution of today's most prominent field feature, the so-called South Atlantic Anomaly (SAA), can be traced back in time with BIGMUDIh.1 (Fig. 2). The SAA is a region of low field intensity (white contour lines in Fig. 2), associated with reverse flux patches (RFPs) at the core-mantle boundary (CMB). Since 1500 CE this anomaly has moved westward from Africa towards South America, where its center (white star in Fig. 2) is currently located. This evolution is driven by growth and movement of RFPs below Africa, Patagonia and higher Southern latitudes.

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