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Resolving 70 Million Years of Earth's True Polar Wander and Precession: Paleomagnetic Validation of a Seismic Tomography–Based Mantle Convection Model

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Mantle convection alters Earth's ellipsoidal shape and modifies its moment of inertia, leading to rotation-axis shifts known as true polar wander (TPW). By combining seismic tomography with the Back-and-Forth Nudging (BFN) method, we created a time-dependent convection model that reconstructs mantle density evolution and Earth's moment of inertia over the last 70 million years. This modeling framework closely agrees with independent paleomagnetic data on Cenozoic changes in Earth's rotation pole, notably reproducing the previously unexplained U-turn in TPW around 50 million years ago.

Our results show that TPW can exceed five degrees, despite stabilizing factors such as high viscosity in the lower mantle and Earth's remnant rotational bulge. Verification of predicted variations in Earth's ellipsoidal figure, based on paleomagnetic constraints, provides a robust reference point for forecasting convection-induced dynamic flattening. Over the 70-million-year interval, we document changes in flattening that range from -0.2% to +0.1% during the Paleogene. Furthermore, our predictions of Paleogene axial precession frequency align with recent independent cyclostratigraphic analyses, offering strong evidence for the accuracy of our model and reinforcing the hypothesis of diminished luni-solar tidal dissipation during that period.