EGU25-3805, updated on 20 May 2025
https://doi.org/10.5194/egusphere-egu25-3805
EGU General Assembly 2025

300 Million Years of Mantle Dynamics: Subduction, True Polar Wander, and Earth's Surface Evolution

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We begin with a simple mantle dynamics model that integrates subducted lithosphere and large-scale upwelling plumes over the last 300 million years (Ma). Our calculations are performed using several plate models and mantle reference frame models, which are constructed based on various surface indicators, including geological data, thermal data from boreholes, a compilation of global surface volcanism, a reassessment of hotspot classifications, and paleomagnetic data.

A Monte Carlo approach identifies the optimal mantle viscosity and density contrasts that explain present-day geoid, gravity, and gravity gradients. Results highlight a consistent degree-2/order-2 mantle mass anomaly over 300 Ma, linked to the stable subduction girdle around the Pacific Ocean and two equatorial, quasi-antipodal mantle domes.

Time-dependent calculations of the Principal Inertia Axis (PIA) and True Polar Wander (TPW) reveal significant shifts in Earth's rotation axis, including cusps caused by the cessation of Paleo-Tethys and Tethys subduction and notable polar wander events .

Dynamic topography is computed and compared with geological and current observations, providing further insight into mantle dynamics and Earth's surface evolution.