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Integrating models and data of the solid Earth using the Advanced Solver for Planetary Evolution, Convection and Tectonics

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Over the past decade and together with a group of international collaborators, we have developed the Advanced Solver for Planetary Evolution, Convection and Tectonics (ASPECT, https://aspect.geodynamics.org/) —research software building on modern numerical methods and showing parallel scaling up to >100,000 compute cores. ASPECT has been widely used to simulate the Earth's mantle and crust, their interaction with the core, the surface, the oceans, ice sheets, and the atmosphere. We now aim to apply ASPECT to integrate models and data of the solid Earth into a unified digital representation, allowing us to put observations of Earth's present and past into context—in particular, being able to accurately describe tectonic plate motion, deformation at plate boundaries and within plates, the response of the solid Earth to surface loads such as ice and water, and the participation of the solid Earth in the water and carbon cycles.

As a first step, we have developed global instantaneous 3-D mantle convection models with a heterogeneous density and viscosity distribution based on seismic tomography and weak plate boundaries inferred from a global fault database. Our model achieves a directional correlation to observed GPS data of 95.1%. Plate boundaries that are 3 to 4 orders of magnitude weaker than the surrounding lithosphere and low asthenospheric viscosities are a a requirement for the good fit. Our models emphasize the impact of plate boundary geometry on the direction and speed of plate motions and reaffirm the importance of slab pull in the uppermost mantle as a major plate driving force.

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