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Spectral element simulation of precession driven flows in the outer cores of spheroidal planets

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A common feature of the planets in the solar system is the precession of the rotation axes, driven by the gravitational influence of another body (e.g. the Earth's moon). In a precessing body, the rotation axis itself is rotating around another axis, describing a cone during one precession period. Similar to the coriolis and centrifugal force appearing from the transformation to a rotating system, the addition of precession adds another term to the Navier-Stokes equation, the so called Poincaré force. The main geophysical motivation in studying precession driven flows comes from their ability to act as magnetohydrodynamic dynamos in planets and moons. Precession may either act as the only driving force or operate together with other forces such as thermochemical convection.

One of the challenges in direct numerical simulations of such flows lies in the spheroidal shape of the fluid volume, which should not be neglected since it contributes an additional forcing trough pressure torques. Codes developed for the simulation of flows in spheres mostly use efficient global spectral algorithms that converge fast, but lack geometric flexibility, while local methods are usable in more complex shapes, but often lack high accuracy.

We therefore adapted the spectral element code Nek5000, developed at Argonne National Laboratory, to the problem. The spectral element method is capable of solving for the flow in arbitrary geometries while still offering spectral convergence. We present first results for the simulation of a purely hydrodynamic, precession-driven flow in a spheroid with no-slip boundaries and an inner core. The driving by the Poincaré force is in a range where theoretical work predicts multiple solutions for a laminar flow. Our simulations indicate a transition to turbulent flows for Ekman numbers of 10^{-6} and lower.