Fluid response to the inner core's translational oscillations

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On the Earth or on other rocky bodies, a sufficiently strong and directional kinetic energy source, such as an asteroid impact or a massive seismic event, can compete with the gravitational energy associated with the internal layers. If liquid shells are present, solid regions are allowed to translate with respect to the planet's centre. These weak motions are known as translation oscillations. Accurately detecting this motion is important to better constrain the physical properties of planetary interiors, such as the densities of solid and liquid phases. In the Earth, the inner core centre is free to weakly oscillate inside the liquid outer core [1]. Due to the planet rotation, the oscillation is split into three modes—the Slichter triplet—two orbital modes in the equatorial plane and one polar mode along the rotation axis [2].

Previous works focused mainly on the linear calculation of mode periods [1,2]. Our new approach involves the study of the outer core fluid response to these oscillations, in the presence of the planetary magnetic field and rotation. To tackle the non-linear problem numerically, we use XSHELLS, a state-of-the-art magneto-hydrodynamic (MHD) solver for spherical shells [3]. The inner core motion is modelled by parameterized boundary conditions, keeping intact the spectral code's efficiency.

We have conducted a systematic exploration of the parameter space, by varying inner core radius, kinematic viscosity and magnetic diffusivity, forcing amplitude and frequency, as well as magnetic field intensity and distribution. We have obtained robust scaling laws for the viscous and Ohmic dissipation, which are employed to extrapolate the associated damping time to planetary conditions that exceed our numerical capabilities. In addition, we have identified several hydrodynamic and MHD regimes. As an example, inertial waves emerge when the oscillation period exceeds half of the spin one, as observed experimentally for the equatorial modes [4]. Furthermore, we have investigated the presence of boundary layer instabilities, and the role of mean zonal flows produced by non-linear interactions.

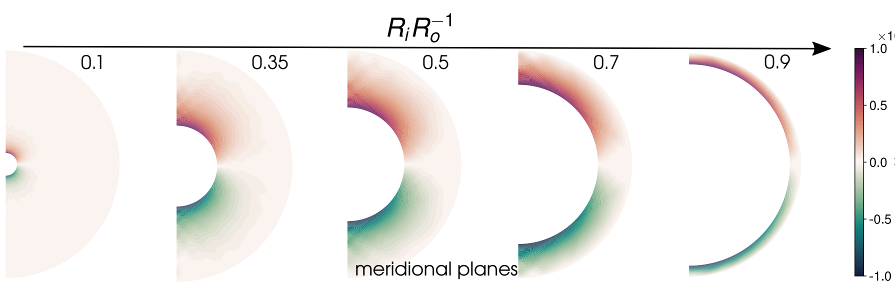

Figure 1. Effect of the inner core radius on the velocity distribution.

References

1. Busse, F.H., On the free oscillation of the Earth's inner core. *J. Geophys. Res.*, **79**(5), 753–757 (1974).
2. Rieutord, M., Slichter modes of the Earth revisited. *Phys. Earth Planet. Inter.*, **131**(3-4), 269–278 (2002).
3. Schaeffer, N., Efficient spherical harmonic transforms aimed at pseudospectral numerical simulations, *Geochem. Geophys. Geosyst.*, (14-3) 751-758 (2013).
4. Subbotin, S. and Shiryaeva, M., On the linear and non-linear fluid response to the circular forcing in a rotating spherical shell, *Phys. Fluids*, **33**(6) (2021).