Topographic effects in magnetized and stratified planetary fluid layers

Rémy Monville*[1], David Cébron[1], and Dominique Jault[1]

[1]Institut des Sciences de la Terre – Institut National des Sciences de l'Univers, Institut de recherche pour le développement [IRD] : UR219, Université Grenoble Alpes, Université Gustave Eiffel, Centre National de la Recherche Scientifique : UMR5275, Université Savoie Mont Blanc – France

Résumé

The interactions between planetary fluid layers and their solid boundaries are an essential aspect when looking at the flow dynamics, but also the motion of the whole body. These couplings are not straightforward to calculate and can originate from pressure, gravity, viscous, or electromagnetic forces.
This topic has been widely explored in atmospheric and oceanic sciences but also has an interest for planetary interiors (e.g., liquid cores, magma oceans of exoplanets, subsurface oceans of icy moons). We thus need models combining rotation, stratification, and magnetic fields.

Unlike the other objects of the solar system, Earth and Moon's rotations are tracked very accurately, and these data are inverted through rotation models to quantify the coupling between the liquid core and the solid layer. Despite these very well constrained values, the coupling mechanisms are still disputed.
In this work, we focus on the small-scale topographic effects which give rise to pressure forces, or increase the electromagnetic coupling, when a fluid flows over a bumpy solid boundary.

To explore these questions, we develop a local model based on plane wave perturbations, following the work of Jault (2020) and Glane (2018). Relying on symbolic and arbitrary precision calculations, our code ToCCo (https://github.com/monvilre/ToCCo) unlocks several limitations of previous calculations. With our "higher-order" solutions, we go beyond the forced wave linear regime, investigating non-linear effects and improving previous results. With this new approach, we explore a wide range of parameters and boundary conditions for arbitrary topography shapes. We also take into account the spherical geometry, through a spatial integration that considers the variation of physical fields. To do so, we have implemented the "improved beta-plane" approximation of Dellar (2011), both for the magnetic field and the rotation vector.

*Intervenant