Topographic effects in planetary magneto-hydrodynamic flows

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

Univ. Grenoble Alpes, Univ. Savoie Mont Blanc, CNRS, IRD, Univ. Gustave Eiffel, ISTerre, 38000 Grenoble, France
remy.monville@univ-grenoble-alpes.fr

While mechanical couplings between fluid and solid domains have been widely studied, their estimation remains challenging for deep planetary fluid layers with buoyancy, magnetic field, and topographic effects. Results from atmospheric or oceanic sciences are unsuitable for thick layers such as subsurface oceans of icy moons, or liquid cores of planets. Rapid rotation and/or the presence of a magnetic field in these regions may also cause difficulties. Considering a rotating and stratified fluid layer, we have developed an asymptotic local model to investigate the small-scale topographic fluid-solid coupling due to pressure or magnetic stresses. Our code unlocks several previous limitations of planetary coupling studies. Considering three-dimensional bumps, it provides the fluid stress at higher order of perturbation than previous linear studies, on an electrically conducting solid (e.g. the mantle lowermost layer). We explore a wide range of parameters and boundary conditions for arbitrary topography shapes, and account for planetary curvature effects by considering a "non-traditional β-plane" approximation. Carrying out a detailed study of the wave drag mechanism, we show that the Rossby planetary waves, which are absent from recent asymptotic models, can significantly modify the boundary stress. We also show that the results are drastically different when considering 3D topographies instead of ridges.

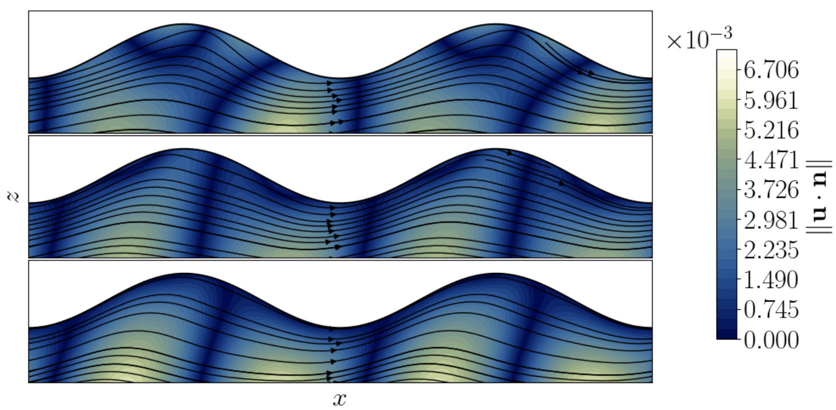

Figure 1. Flow streamlines and $\|\boldsymbol{u} \cdot \boldsymbol{n}\|$ (with an artificial normal vector $\boldsymbol{n}$ defined in the whole volume) field at order 1,2 and 4 (top to bottom).