FD2.5 – Quasi-static magneto-hydrodynamic convection in a rotating cylinder

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We present a numerical study on the topic of magnetoconvection in a cylinder under the quasi-static magneto-hydrodynamic approximation using a spectral-element solver. The aim of this work is to obtain a better understanding of the convection process in planetary cores, in particular the formation of anticyclonic polar inside the tangent cylinder. The secular variation of the Earth's magnetic field points to the existence of anticyclonic polar vortices in the Earth's core [2]. We consider the motion of an electrically conducting fluid in a closed cylinder with electrically insulated boundaries. An external homogeneous magnetic field $\mathbf{B_0}$ is imposed across the cylinder length. In this work is used the quasi-static approximation, such that the agglomerated magnetic field is indistinguishable from $\mathbf{B_0}$. We also work under the Boussinesq approximation.

The governing equations are solved using the spectral-element code Nektar++. In this the computational domain is divided into elements where the variables are projected within a polynomial basis within each element. We will be conducting a linear analysis of the system is order to find steady states. Then branch tracing, using a Newton-Raphson solver, will be used to study the phase space and find potential bifurcation points as well as obtain nonlinear solutions of the problem in function of the magnetic field and convection strength and how they compare to experimental data. Another question we seek to answer is the importance of the wall-modes for strong magnetic fields.

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Geophysics and porous media

GP1.1 (invited) – Dynamical landscape and multistability of a climate model

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We investigate the multistability properties of a hierarchy of climate models. We first show how to construct the Melancholia states, chaotic saddles included in the basin boundaries of the competing attractors [1], Drawing from the theory of quasi-potentials, we infer the relative likelihood of the identified metastable climate states when stochastic perturbations are included. We investigate the most likely transition trajectories as well as the expected transition times between them [2, 3]. In the case of the most complex model considered here, we complement classical numerical modelling with techniques from data science, and specifically manifold learning, in order to characterize the data landscape within a fully agnostic and unsupervised framework. We discover that that the topography of the dynamical landscape of the model becomes considerably more complex, as stronger macroscopic currents appear in the phase space, implying that the system is farther away form equilibrium conditions. We attribute this to the enhanced entropy production due to the presence of an active hydrological cycle. In a model configuration, our analysis reveals, apart from the well known warm and snowball Earth states, a third intermediate stable state. Finally, we propose conceptual framework for understanding the multiscale nature of the multistability of the climate system [4].

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