EARTHSCIENCES

Powering a geodynamo with tides of the core

Primary supervisor:	*Richard F Katz — https://foalab.earth.ox.ac.uk/*
Co supervisor(s):	*David Marshall (Physics)* *Ian Hewitt (Mathematics)*
Key words:	Geodynamo, fluid dynamics, tides, magnetic field
Research theme(s):	• Geophysics and Geodynamics • Planetary Evolution and Materials • Oceanography, Climate and Palaeoenvironment
Eligible courses for this project:	• DPhil in Earth Sciences • Environmental Research (NERC DTP)

Overview

Earth's global magnetic field is the consequence of a geodynamo: a magnetohydrodynamic system in which rapid flows of an electrically conducting fluid (liquid iron) produce electrical currents and strong magnetic fields. This system dissipates energy and hence its maintenance requires a steady input of energy. Today that energy supply comes from the gravitational potential of liquid iron alloy that is enriched in light elements by solidification of the inner core. That less-dense fluid rises and powers a convective flow that is modified by the Coriolis and Lorentz forces. Convection associated with secular cooling and inner-core growth can thus drive a geodynamo.

Early in Earth history, there was a geodynamo but no solid inner core. What was the power source at that time? It could again have been convection: exsolution of light elements at the core–mantle boundary may have created denser iron liquid, or solidification of iron at the CMB may have created an iron snow. But both of these require that temperatures at the CMB were significantly diminished from the initial core temperature, which raises issues with the longer term evolution of the core.

Another possibility for driving the early geodynamo is tides. Tides convert the rotational kinetic energy of an orbital system (e.g., the Earth–moon system) into the kinetic energy of a flow. When the moon was closer to Earth, the available tidal energy would have been significant. This DPhil project aims to develop tidal mathematical and computational models of the outer core and analyse them in terms of their potential to contribute to dynamo generation or maintenance.

Methodology

The project will use methods of applied mathematics to simplify the physics, generate solutions, and analyse those solutions. Perturbation methods will be used to seek analytical solutions to the tidal response, and these will be extended with semi-analytical treatment of the effects of rotation. Spectral decomposition will be used to obtain numerical solutions of tidally driven flow in nonlinear regimes.

Tidally driven flows will be analysed in terms of their Reynolds number and kinetic energy in the first instance. Later, flows may be coupled to the magnetic induction equation to investigate how they could modify a magnetic field. The project may also use an existing MHD code to look at cases where convection and tides simultaneously inject energy into the flow.

Timeline

Year 1: training in geomagnetism, fluid dynamics, tides, MHD and computational methods. Development of highly idealised models by perturbation theory.

Years 2 and 3: Elaboration of basic models by incorporation of rotation with semi-analytical solution methods. Development of a numerical solver for tidal problems. First publication(s).

Year 4: Extension of models to include solution of the induction equation and analysis of magnetic-field modification. Exploration of MHD geodynamo simulations that couple convection and tides.

Training & Skills

The student will attend one or more international summer schools on topics that may include fluid dynamics, convection, MHD and geodynamos.

References & Further Reading

Landeau, Maylis, et al. Sustaining Earth's magnetic dynamo. *Nature Reviews Earth & Environment* 3.4 (2022): 255-269.

Le Bars, Michael, David Cébron, and Patrice Le Gal. Flows driven by libration, precession, and tides. *Annual Review of Fluid Mechanics* 47.1 (2015): 163-193.

Chandrasekhar, Subrahmanyan. The oscillations of a viscous liquid globe. *Proceedings of the London Mathematical Society* 3.1 (1959): 141-149.

Further Information

Contact: Prof Richard Katz (richard.katz@earth.ox.ac.uk)