Subject offered for a contract starting October 2018

SUBJECT TITTLE:

Short time scale fluctuations of the geomagnetic field: modelling and interpretation

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Financing: Doctoral contract with or without teaching assignment

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Magnetic data carry key information to understand the dynamic of the liquid outer core where is generated the Earth main magnetic field. This information is not easily retrieved because core field signals have first to be separated from other source signals that are contributing to magnetic field measurements at the Earth surface or at satellite altitude. To achieve this separation it is necessary to build magnetic field models of all main sources and provide prior information on their spatial and temporal behaviours. Yet, current models of the core magnetic field fail to describe precisely its temporal variations, in particular for the field shorter time scales – e.g. Finlay et al. (2016), Lesur et al. (2015). These are linked to poorly understood transient perturbations, or wave propagations, in the liquid outer core flow. Describing these perturbations is a fundamental step for understanding the short-term dynamics of the liquid outer core and therefore being able to predict the main field behaviour over few years. The overarching goal of this PhD project is to study through careful data analyses these fast core field variations and interpret them as flow patterns in the outer core. It is part of a larger project that aim at modelling all magnetic field contributions to eventually being able to predict the field behaviour and assimilate magnetic data as they become available.

For this modelling effort a large set of magnetic observatory data is available starting in the 1950's, which is complemented since year 2000 by magnetic survey satellite data. Modelling fast variations of the magnetic field contributions, with time scales much shorter than a year, over more than six decades requires models that are excessively large even for modern computers. To circumvent this difficulty it is possible to put in place and iterative scheme, based on a Kalman filter and smoother, combined with a correlation based modelling (Holschneider et al., 2016) where the prior information is provided through covariance matrices. Data can therefore been assimilated month after month, or even on shorter time scales, where prediction from one epoch to the next is achieved through a stochastic process. Such an approach has been set for modelling the core field secular variation from observatory data (Lesur et al., 2017), but has never been implemented for satellite data. The challenge for this type of data is handling the highly variable magnetic fields at high latitudes generated in and above the ionosphere. These fields have been identified as the main limitation for building high-resolution core field model.

The flow at the top of the liquid outer core has to be estimated from, or possibly co-estimated with, the core field model (Lesur et al., 2015). Here again an approach based on Kalman filter and correlation modelling can be applied. The expected improved temporal resolution of the field model should reveal rapid transient perturbations of the core flow. At least, torsional waves at five to six year or shorter periods (Gillet et al., 2015) should be identified. The aim would be then to track their evolution in time, to evaluate their attenuation rate, to estimate how often they are excited, and possibly to find the mechanism that trigger the waves.

The PhD candidate will have first to learn about the magnetic data set characteristics, the different magnetic fields contributing to satellite and observatory data, and about different mathematical techniques for modelling the field. The data selection process, the field and the flow modelling activities will be strongly supported by an existing large set of available FORTRAN subroutines. Therefore, even if significant programming and numerical work is expected, his or her work will be mainly dedicated to the control of the data inversion process by introducing relevant geophysical information.

International collaborations: A close collaboration with Julien Baerenzung (Potsdam University) is planned. He has carried out a series of core flow inversion (see e.g. Baerenzung et al., 2016), and standout as a specialist of correlation methods and Bayesian inferences in geomagnetism. The successful candidate will have the opportunity to visit him in Potsdam over the course of the project. In addition, a project on similar subject is running for the next two years involving IPGP's geomagnetic research group and Kyoto University. The candidate will also have the opportunity to join this group.

Collaboration inside IPGP's is also expected with Julien Aubert in order to access information on the expected core flow behaviour derived from numerical simulation of the Earth geodynamo.

We seek a highly motivated candidate with a background in geophysics, in particular geomagnetism and inverse problem theory. Experience in scientific computing is a plus.

References

Baerenzung, J., Holschneider, M., and Lesur, V. (2016), The flow at the Earth's core mantle boundary under weak prior constraints, J. of Geophys. Res. (Solid Earth), 121(3):1343– 1364, doi:10.1002/2015JB012464

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Gillet, N., D. Jault, and C. C. Finlay. (2015), Planetary gyre, time-dependent eddies, torsional waves and equatorial jets at the Earth's core surface. J. Geophys. Res. (Solid Earth), 120(6):3991– 4013.

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