Dynamics and Implications of Geomagnetic Field Variations: Signal Extraction from 150 Years of Geomagnetic Observatory Data

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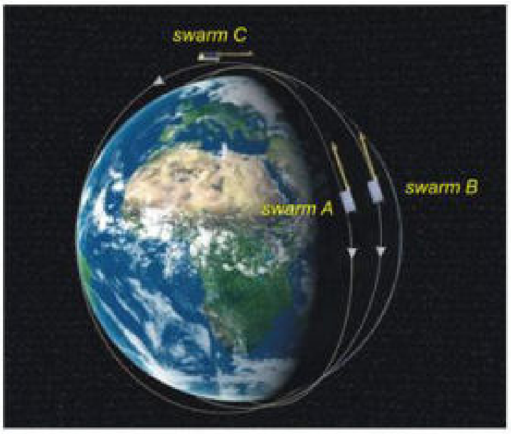
The secular variation (change with time) of the geomagnetic field is a powerful probe of the structure and processes of the deep Earth, in particular of mantle conductivity, flow at the top of the core, and constraints on core dynamics. Recent years have seen major advances in understanding of the field, particularly driven by large quantities of data provided by low-Earth orbiting satellites dedicated to measuring the geomagnetic field: Ørsted, CHAMP, and SAC-C. Further improvements are expected from the ESA Swarm mission (cartoon below right), planned for launch in 2009-10. Nonetheless, the insight that can be gained from these data is limited by their duration: internal Earth processes varying on decadal time scales are of particular interest, and the era of satellite data is too short to constrain such processes adequately. The more than 150-year historical record provided by geomagnetic observatories is crucial in this respect, especially because as the observatories measure the field at a fixed location over long periods, they remain the most sensitive tool to constrain the time change of the field.



With the new insights provided from analysis of satellite data, particularly from the currently running NERC GEOSPACE consortium, the time is ripe for detailed re-examination of the historical record for what further insights it may yield concerning the Earth system. Possible subjects of interest include:

- Use of magnetic activity as a measure of solar input to climate change. The Aa index shows strong correlation with temperature records up to around 1990. Can this be confirmed for earlier epochs prior to 1870 by examining the most complete observatory records?
- High-resolution secular variation prior to 1900. Observatory data show consistent residuals to historical field models prior to 1900. It is highly probable that these signals reflect details of changes in core surface flow.

- Geomagnetic jerks. Improved understanding of external sources of field allow “cleaning” of observatory data, allowing constraint on the detailed structure of secular variation impulses, and so of the electrical conductivity of the lower mantle and of core flow impulses.
- Deep mantle geomagnetic sounding using solar cycle variations. Accounting for geomagnetic jerks is crucial in this study.
- Quiet time daily variation modelling, particularly separating ionospheric and magnetospheric signals, to allow improved geomagnetic sounding of upper mantle electrical conductivity.
- Ionospheric signals as recorded by observatories, particularly in auroral and equatorial locations. These signals represent the largest source of uncertainty in current global field modelling, and their better constraint is crucial for progress in many other areas of geomagnetic field study.
- Oceanic motional induction signals as recorded in observatory data.

The student will work with a large archive of magnetic data freely available from world data centres. The historical components of the study will also require archive study, particularly at the holdings of the British Geological Survey geomagnetism group at Hartland magnetic observatory (pictured above). Some time will also be spent in Edinburgh with the geomagnetism subgroup from British Geological Survey. Considerable effort will be devoted to optimising signal extraction from the data by modelling of noise sources, an area in which the lead supervisor has significant experience. The data will be examined in the framework of modern magnetic field modelling programmes, particularly the Comprehensive model, and the various models emerging from recent satellite missions. Some code development is likely to be necessary, so expertise in scientific programming is advantageous, but the results will integrate into studies of field and core-flow modelling, for which fully developed code is already available. Further training will be available in this area, and in geophysical inverse theory. The student will also participate in the Departmental and University Postgraduate training programme. For students who hope to progress in a research career, it is probable that the launch of the Swarm constellation at the completion of the PhD will provide many opportunities for further career progression, for which this study will provide a strong preparation.

Recent publications relevant to research area

- Cliver EW, Boriakoff V, Feynman J, 1998. Solar variability and climate change: Geomagnetic aa index and global surface temperature. Geophys. Res. Lett. 25, 1035-1038.
- Mandea M, Bellanger E, Le Mouel JL, 2000. A geomagnetic jerk for the end of the 20th century? Earth Planet. Sci. Lett. 183, 369-373.
- **Holme R**, Olsen N, 2006. Core surface flow modelling from high-resolution secular variation. Geophys. J. Int., 166, 518-528.
- Wardinski I, **Holme R**, 2006. A time-dependent model of the Earth's magnetic field and its secular variation for the period 1980-2000. J. Geophys. Res., 111, B12101.

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