THE UNIVERSITY of EDINBURGH

Job Description

Internship Title: What happened in the core in 2010?

Department/ School	Grant Institute, School of Geosciences, University of Edinburgh
Reports To	Frederik Dahl Madsen. F.d.madsen@sms.ed.ac.uk. University of Edinburgh & British Geological Survey Will Brown. wb@bgs.ac.uk. British Geological Survey Kathy Whaler. Kathy.Whaler@ed.ac.uk. University of Edinburgh

Job Purpose

This job involves investigating models of the geomagnetic field and the flow at the surface of the Earth's liquid outer core, and observations of Earth's rotation, for periodic trends. Supported by the supervisory team, the student will adapt and develop existing python code to extract spatiotemporal information about the outer core environment from 1997 to 2025.

Main Responsibilities

- Develop code for PCA and joint PCA in the context of the Earth's core. (30%)
- Investigate periodic trends in each of the three data sets, using HHT and CWT: (25%)
    - Geomagnetic secular variation (10%)
    - Core-surface flow (10%)
    - Length-of-day (5%)
- Compare principal components to observed behaviour in length-of-day data (20%)
- Communicate the findings to the wider research community (10%)
- Other (Including induction sessions, Eskdalemuir trip, and PRGiP if appropriate) (15%)

Knowledge Skills and Experience (required for the role)

Attribute	Essential	Desirable
Education, Qualifications & Training	- Mathematics and physics at 'A' level, Highers, IB Higher Level, or equivalent - Basic scientific programming skills	- Knowledge of Fourier theory - Knowledge of electromagnetism -

Knowledge & Experience	- Basics of computer programming and handling digital data	- Basic knowledge of geophysics - Good communication skills to disseminate results - Python computing skills

Person Specification

Planning and Organising

- -Ability to structure and manage a computational research project
- Ability to break down larger problems into solvable chunks

Problem Solving

- Ability to design and test scientific code
- Ability to work independently

Decision Making

- Critical thinking skills, and the ability to make decisions on analysis, based on intermediate results.

Key Contacts:

- Work with Frederik Dahl Madsen day to day.
- Work with Frederik Dahl Madsen and Prof. Kathy Whaler on understanding core-surface flow models.
- Work with Dr. Will Brown on using principal component analysis.

Dimensions

Closing date for applications: Wednesday 14th May 2025 (Midnight)
Start date: This project is estimated to take **8 weeks**, and is fully flexible. If the candidate wishes to attend PGRiP, they would need to be free between 27th - 29th August, 2025, and able to travel to and from Norwich (finances covered by the project).
Hours per week and preferred pattern/ restrictions (if applicable): 35 hours per week

Additional Information

Project Outline

This project is co-hosted by the University of Edinburgh's School of GeoSciences, and the Geomagnetism team at the British Geological Survey (BGS).

The Earth's magnetic field is governed by the flow of liquid iron in the Earth's outer core. Over the past 400 years, the field changes have been dominated by westward drift at a quasi-steady rate beneath the hemisphere centred on the Greenwich meridian, and little change beneath the Pacific Ocean. From observations of these changes – also referred to as secular variation – we can infer the structure of the core-surface flow.

We can also use observations of Earth's rotation – often referred to as length-of-day – to investigate the Earth's deep interior. The length-of-day changes due to exchanges in angular momentum between the solid Earth and the atmosphere, oceans, lunar tides, and the core.

Therefore, by removing the effects of the lunar tides and surface fluids (i.e., atmospheres and oceans), we can isolate the angular momentum transfer between the core and the mantle. Many studies with focus on this (e.g. Madsen and Holme, in review) all highlight an oscillatory signal of 6 years – thought to arise from gravitational coupling between the solid inner core and the mantle – and 8 years – believed to arise from fluid motions in the liquid outer core.

In models of core-surface flow, the large-scale flow is predominantly westward, and recent studies now suggest wave-motion propagating along the equator (e.g. Grüne et al., in review). However, after 2010, we see a change in the flow underneath the Pacific Region from weak westward to strong eastward flow (Ropp & Lesur, 2023; Madsen et al., 2025). This change in fluid-flow morphology is contemporary with a change in the shape of the Earth's inner core (Vidale et al., 2025), and an interruption in the 6-year oscillation in length-of-day (Madsen and Holme, in review), but the link between these observations is yet to be made.

The purpose of this project is to investigate secular variation, models of the core-surface flow, and length-of-day variations, for periodic signals. The student will be working on pre-existing datasets of secular variation from satellite data (available online from the European Space Agency), pre-existing core-surface flow models derived from ground- and satellite data (Grüne et al., in review), and a pre-existing length-of-day series, cleaned of external (atmospheric, oceanic, and tidal) signals (Madsen and Holme, in review). They would employ spatiotemporal methods such as principal component analysis (PCA; Cox et al., 2018, and Anh, 2022), and common time-series analysis techniques such as Hilbert-Huang Transforms (HHTs) and continuous wavelet transforms (CWTs), to answer the following four questions:

1. Are there any dominant periods in each of the three datasets (secular variation, core-surface flow, and length-of-day variations)?
2. If so, is there an overlap in these periods across the three datasets?
3. For secular variation and core-surface flow, is there any spatial association with such periods?
4. Does the periodic behaviour of these datasets change in 2010?

Alongside developing experience in deep Earth geophysics, the student will get a chance to develop their skills in time series analysis and spectral analysis, which have wide applicability in all branches of science. In the first week, the student will be welcomed to the Grant Institute, and receive an introduction to geomagnetism, Earth's rotation, and core-surface flow modelling at the University of Edinburgh by Frederik Dahl Madsen, to bring them up to speed with the required knowledge for the project. Thereafter, they will the receive the necessary support to set up good practise for computing the project, and an overview of the necessary packages and pre-existing code for time-series analysis. Also during the first week, the student will spend a day at The Lyell Centre, BGS, meeting the geomagnetism team at the BGS and learning what they do, and getting an introduction to their *MagPySV* PCA python library and the general handling of geomagnetic data.

After this, the student is expected to work largely independently on utilising and adapting the pre-existing PCA libraries and time-series analysis techniques for investigating the three datasets, with regular supervisor meetings for feedback, support and guidance (supervisors will be available to respond to queries at other times). Minimum one day per week spent at the BGS, and one day a week spent at the Grant Institute is strongly encouraged.

During the placement, the candidate will get a change to join the monthly BGS Geomagnetism Seminars, in which researchers, both UK-based and international, share recent progress on their science, and will be given the opportunity to present their findings at this seminar at the end of their placement. The student will also visit the BGS Geomagnetic Observatory in Eskdalemuir at some point in the summer (date to be set with the student) and will be given the option to attend the British Geophysical Association (BGA)'s Postgraduate Research in Progress (PGRiP) meeting in Norwich, on the 27th-28th August.

References:

- Anh, L. T. (2022) PCA for Time Series Decomposition. Kaggle notebook. url: https://github.com/LeoTungAnh/PCA_SSA [Last accessed 10/04/2025].
- -Cox, G. A., Brown, W. J., Billingham, L., & Holme, R. (2018). MagPySV: A Python package for processing and denoising geomagnetic observatory data. *Geochemistry, Geophysics, Geosystems*, 19, 3347–3363.
- Grüne, C., Whaler, K. A., Madsen, F. D. (In review). Detecting Waves in Core Surface Flow Acceleration Derived from 25 Years of Secular Variation. *Physics of the Earth and Planetary Interiors.*
- Madsen, F. D. & Holme, R. (in review). A recent interruption in the six-year oscillation in length-of-day, *Geophysical Journal International.*
- Madsen, F. D., Whaler, K. A., Beggan, C. D., Brown, W., Lauridsen, J. B., Holme, R. (2025). Modelling geomagnetic jerks with core surface flow derived from satellite gradient tensor elements of secular variation. *Physics of the Earth and Planetary Interiors,* (in press).
- Ropp, G. & Lesur, V., 2023. Mid-latitude and equatorial core surface flow variations derived from observatory and satellite magnetic data, *Geophysical Journal International*, 234(2), 1191–1204.
- Vidale, J. E., Wang, W., Wang, R., Pang, G., & Koper, K., 2025. Annual-scale variability in both the rotation rate and near surface of Earth's inner core, *Nature Geoscience*, 18(3), 267–272.

Budget

A maximum of £500 towards project costs is available.

Location

Based primarily at the Grant Institute, James Hutton Road, Kings Buildings, EH9 3FE, where a desk, laptop, and monitors are provided. However, you will also visit British Geological Survey, Lyell Centre, Research Avenue South, EH14 4AP, Edinburgh, on average once a week throughout the placement.

Health & Safety Requirements for the role

None

Key Job hazard information specific to the role

Stationary work based at desk behind screen.

Programme Information

The Research Experience Programme (REPs), funded by NERC, offers paid research opportunities for undergraduate students. The programme is designed to address both demographic and diversity challenges in the environmental sciences, as well as thematic skills gaps, such as quantitative skills.
This is a valuable opportunity to gain hands on research experience, boost your employability, and explore potential pathways into further study or careers in environmental science.

For full details on how to apply and the selection process, please visit our REP webpage

Application Support

The University's Careers service provides a wide range of resources to support your application, including guidance on CVs, cover letters, and interview preparation.
Students undertaking a REP placement will also have the opportunity participate in the Edinburgh Award - a structured programme that helps you reflect on and gain recognition from the University for the skills and attributes developed during your internship.
For more information, you can book an appointment with a Careers Consultant via MyCareerHub.

Eligibility Criteria

To be eligible for a REP placement, applicants must meet **all** of the following criteria:

• Be currently studying towards their first undergraduate degree studies (including integrated Master's degrees) in a UK Higher Education institution, in any science discipline
Note: *Final year students are eligible if they still hold student status at the* ***start of the placement,*** *even if the student graduates during the course of the placement.*

- Be eligible for subsequent NERC PhD funding as defined here:
- A UK citizen who has been living in the UK for at least the past 3 years OR
- An EU citizen with pre-settled or settled status under the EU Settlement Scheme OR
- A non-EU citizen who has obtained the right to remain in the UK - known as 'indefinite leave to remain' (ILR) OR
- An International/EU student currently studying in the UK under a Tier 4 or Student Route Visa with validity until at least September 2025.

REPs **do not** meet the requirements for visa sponsorship. As such, students who are not currently residing in the UK or who do not hold a valid UK visa are not eligible to apply.

You cannot take part if you are a visiting student, or have previously taken part in REP programme.

Privacy Statement

In addition to the University's HR Privacy Information Notice, please read the Student and Graduate Privacy Statement: Internships and work experience programmes to understand how your personal information will be collected, used, and stored as part of the application process. .

If you require this document in an alternative format, please email us at: e5dtp.info@ed.ac.uk