Research Experience Placement (REP) Scheme Project

Project Supervisors:
Dr. John Ross and Dr. Sarah Glauert

Host Organization and Department (if applicable):
British Antarctic Survey, Space Weather and Atmospheres

Project Title:
Probabilistic radiation belt forecasting

Project Description:

The Earth is surrounded by regions of changed particles, known as the radiation belts, which exhibit extremely dynamic behaviour driven by fundamental physical processes. Satellites travel through these belts and can be damaged by the particles, leading to anomalous behaviour and outages. The space industry is rapidly expanding with thousands of satellites being launched over the next few years (Starlink, OneWeb). Understanding the driving processes and predicting the radiation environment is imperative for reducing the risk to these satellites.

The project aim is to develop a probabilistic radiation belt model using novel statistical modelling methods. The applicant will develop the model using the Ensemble Kalman Filter technique that has recently become popular and successful in meteorology but has only recently been applied to radiation belt physics. The method allows for the uncertainty in the system to be included to give a prediction and an associated probability, significantly improving forecasting capabilities and our understanding of the variability.

Electrons in the radiation belts are lost via interactions with magnetospheric waves, and collisions with the Earth's atmosphere, while ultra-low frequency waves diffuse the particles towards and away from the Earth. The applicant will write a diffusion model that captures the radial transport and the losses processes. There is a great deal of uncertainty in these processes, which the student will include into the diffusion model by varying existing empirical models. They will develop the Ensemble Kalman Filter model around the diffusion model by combining with satellite observations.

Skills and Career-Development Opportunities:

The applicant will learn about state-of-the-art statistical forecasting techniques which have a wide range of real-world applications from environmental science to economics. They will develop Python coding skills for data handling, visualization and model development. This will include learning and following good coding practices such as version control using Git.

The student will gain an understanding of the physics controlling the radiation belts including the driving processes such as wave-particle interactions and radial diffusion. The student will learn about the risks caused by space weather to the space industry and how scientific understanding of the near-Earth environment can reduce these risks.

Wider context of research:
There will be opportunities to learn about ground-based instruments used in space weather monitoring (radars, magnetometers, VLF receivers, radiometer) from the instrument PIs and engineers at BAS. The student will use satellite data and will learn about the instruments making the measurements. Through the regular program of talks, students will be exposed to the science within the Space Weather and Atmosphere team and to the wide variety of science that is carried out at BAS. The student will be able to attend the MIST (Magnetosphere, ionosphere and Solar-Terrestrial) and Wave Particle interaction sessions at the virtual National Astronomy Meeting (2 days between 19th-23rd July) to get a wider understanding of space weather research.

Project Timeframe:
The placement will be for 8 weeks with the following project timeline: Week 1: The student will gain familiarity with the Earth's radiation belts and space weather instruments. Week 2-5: Write a 1D radial diffusion radiation belt model (based on an existing formulation) with electron losses included by (existing) geomagnetic activity parametrised empirical models. Weeks 5-6: Develop the 1D model into an ensemble of simulations by varying geomagnetic activity in the empirical models. Weeks 7-8: Extend the ensemble to an Ensemble Kalman Filter model by combining with (already processed) satellite observations. The student will work under the guidance of Dr. John Ross and Dr. Sarah Glauert at each stage of the project, with regular discussions on the approach and the results.