Dynamical networks analysis and modelling of space weather observations

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Space weather events can have a high impact over a wide range of systems, from power supplies, aviation, satellites and radio communications to economic and social behaviour. They are becoming increasingly important as our society relies more and more on being interconnected. This project will utilize the extensive datasets available from ground based magnetometers which observe the impact of geomagnetic activity at earth- 'space weather'. The overall challenge is to characterize these 100+ timeseries with meaningful and informative time dependent network parameters. This will then allow many events to be compared in a quantitative manner. Space weather 'end users' require a few parameters or 'flags' that indicate likely space weather severity and impact on ground systems and this is the ultimate aim of this line of research.

MSc Project: In particular we can construct directed networks which capture information propagation across the system. In this MSc project we will focus on PC waves which are resonant standing Alfven waves that are excited on the closed magnetic field lines of the earth's dipole field. These resonant waves are excited by the injection of energetic particles into the inner magnetosphere following a space-weather event and may provide a precursor or warning for changes to the Van Allen radiation belts that affect satellites in geostationary orbit. The project will be to construct directed networks for the PC waves to quantify how their activity evolves in space and time.

The project requires calculating estimates of canonical cross-correlation and coherence between vector timeseries based on a Fourier or Wavelets approach. The cross-correlation matrix is then used to form the directed networks. This can be performed in Matlab or python. A basic review of the physics of space weather impacts is also required.

This approach is quite new and a publication on the spatio-temporal pattern of PC wave excitation and propagation under active space weather conditions in a mainstream geophysics journal is anticipated.

The fully calibrated and processed data is available via the SuperMAG project:

http://supermag.jhuapl.edu/

SuperMAG PI Jesper Gjerloev (John Hopkins University/Applied Physics Laboratory) is one of our collaborators and a project partner. The UK project partner is Malcolm Dunlop (Rutherford Appleton Laboratory, also visiting Professor, University of Warwick). These datasets are from 100+ magnetometers and extend over several (11 year) solar cycles at minute cadence. The SuperMAG project has calibrated the data onto a uniform background and uniform time-base so that it is ready for network analysis.

Prospects for follow-on PhD project: This methodology is quite general and can be applied to other aspects of space weather and to other datasets, in addition to ground based magnetometers for example, multipoint observations of ionospheric Total Electron Content (in collaboration with Tony Mannucci at NASA Jet Propulsion Laboratory, Pasadena) and space-based observations (in collaboration with Malcolm Dunlop, RAL). An important data analytics challenge is to use the networks to combine these different data types in a single analysis.