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Quantifying space-weather events using dynamical network analysis of Pc waves with global ground based magnetometers.

Shahbaz Chaudhry[1], Sandra Chapman[1], Jesper Gjerloev[2,3], Ciaran Beggan[4], and Alan Thompson[4]
[1]Centre for Fusion, Space and Astrophysics, Department of Physics, University of Warwick, Coventry, UK
[2]The Johns Hopkins University Applied Physics Laboratory, Laurel, Maryland, USA
[3]Department of Physics and Technology, University of Bergen, Bergen, Norway
[4]British Geological Survey, Edinburgh, UK

Geomagnetic storms can impact technological systems, on the ground and in space, including damage to satellites and power blackouts. Their impact on ground systems such as power grids depends upon the spatio-temporal extent and time-evolution of the ground magnetic perturbation driven by the storm.

Pc waves are Alfven wave resonances of closed magnetospheric field lines and are ubiquitous in the inner magnetosphere. They have been extensively studied, in particular since Pc wave power tracks the onset and evolution of geomagnetic storms. We study the spatial and temporal evolution of Pc waves with a network analysis of the 100+ ground-based magnetometer stations collated by the SuperMAG collaboration with a single time-base and calibration.

Network-based analysis of 1 min cadence SuperMAG magnetometer data has been applied to the dynamics of substorm current systems (Dods et al. JGR 2015, Orr et al. GRL 2019) and the magnetospheric response to IMF turnings (Dods et al. JGR 2017). It has the potential to capture the full spatio-temporal response with a few time-dependent network parameters. Now, with the availability of 1 sec data across the entire SuperMAG network we are able for the first time to apply network analysis globally to resolve both the spatial and temporal correlation patterns of the ground signature of Pc wave activity as a geomagnetic storm evolves. We focus on Pc2 (5-10s period) and Pc3 (10-45s period) wave bands. We obtain the time-varying global Pc wave dynamical network over individual space weather events.

To construct the networks we sample each magnetometer time series with a moving window in the time domain (20 times Pc period range) and then band-pass filter each magnetometer station time-series to obtain Pc2 and Pc3 waveforms. We then compute the cross correlation (TLXC) between all stations for each Pc band. Modelling is used to determine a threshold of significant TLXC above which a pair of stations are connected in the network. The TLXC as a function of lag is tested against a criterion for sinusoidal waveforms and then used to calculate the phase difference. The connections with a TLXC peak at non zero lag form a directed network which characterizes propagation or information flow. The connections at TLXC lag peak close to zero form am undirected network which characterizes a response which is globally instantaneously

coherent.

We apply this network analysis to isolated geomagnetic storms. We find that the network connectivity does not simply track Pc wave power, it therefore contains additional information. Geographically short range connections are prevalent at all times, the storm onset marks a transition to a network which has both enhancement of geographically short-range connections, and the growth of geographically long range, global scale, connections extending spatially over a region exceeding 9h MLT. These global scale connections, indicating globally coherent Pc wave response are prevalent throughout the storm with considerable (within a few time windows) variation. The stations are not uniformly distributed spatially. Therefore, we distinguish between long range connections to avoid introducing spatial correlation.