3rd URSI AT-AP-RASC, Gran Canaria, 29 May – 3 June 2022

Automated detection and unsupervised classification of dispersionless electron injection events in Earth's magnetotail

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We present a layered algorithm approach for the detection and unsupervised classification of dispersionless electron injection events utilizing MMS data from the tail seasons of 2017 through 2021. Using a Savitzky-Golay filter over cumulative relativistic electron count rates from the Fly's Eye Energetic Particle Spectrometer (FEEPS) (80 – 150 keV), we find approximately 40,000 events over 5 seasons of data, greatly expanding the spatial and temporal coverage (extending up to 30 R_E in Earth's magnetotail) of known injection events. A portion of the events detected in the 2018 tail season was compared with a manual, SME-generated, list of events and we find that the algorithm is able to correctly identify 96% of the labeled dispersionless injections in addition to finding an additional ~3k events on a finer temporal scale. Spatial patterns in the distribution of algorithm-identified events were binned according to driving solar wind conditions and geomagnetic indices to uncover potential physical drivers. We find the spatial distribution of identified events correlates well with previously identified injection mechanisms such as central plasma sheet crossings, bursty bulk flows (BBFs), and magnetotail reconnection, while perhaps finding a new driving mechanism near the magnetopause flanks. In addition to FEEPS data, data from MMS' fluxgate magnetometer (FGM) and Fast Plasma Investigation (FPI) for a finite time period bordering the identified onset of each event were utilized for unsupervised event classification. We explore utilizing Principal Component Analysis (PCA) to reduce the dimensionality of the multi-feature time series data corresponding to each event prior to unsupervised classification of the events. Representative examples from the resulting clusters were then analyzed to assess the ability of the unsupervised learning to both identify and differentiate between known physical processes, using known example cases from the MMS data set. Known example cases spanned physical phenomena including: i) central plasma sheet (boundary) crossings, ii) bursty bulk flows, iii) magnetotail reconnection, and iv) phenomena adjacent to the magnetopause flanks.