Classification of High-Energy Particle Precipitation Events Using Computer Vision

Earth's radiation belts host high-energy particles in a delicate balance which can be disrupted by certain events, such as Electromagnetic Ion Cyclotron (EMIC) waves, resulting in particles falling towards the Earth's atmosphere. This Energetic Particle Precipitation (EPP) can deplete atmospheric ozone, interrupt telecommunications, and destroy sensitive electronic components. For our efforts, we have chosen to direct our focus towards EMIC waves as they have the greatest impact on the aforementioned effects of EPP due to their tendency to precipitate the highest energy electrons and to provide a strong foundation for the future application of our methods to include multiple sources of EPP. Data collected by the twin ELFIN satellites aims to provide researchers with a deeper understanding of this region of space and the varying sources of EPP. We aim to further this field of research by applying the YOLO Computer Vision framework to the ELFIN dataset in order to identify EMIC-induced EPP events. This identification is made possible by the unique data signature of EMIC-induced EPP: an elevated rate of electron precipitation at relativistic (≳500 keV) energy levels which tapers down as energy level decreases. To train a YOLOv8 model, we constructed a labeled training set by isolating EMIC wave events, plotting them against a graph of standardized dimensions displaying the J_{prec}/J_{trap} ratio (the number of electrons which fall into the atmosphere over the number of electrons which are trapped in orbit), and introducing seeded randomness to improve model performance. We present our results of the trained YOLO models and their application towards determining the distribution of EMIC detections in the magnetosphere from ELFIN data. These results are compared with currently published research on EMIC-induced EPP. With our models and findings, future researchers will develop a better understanding of how to predict EPP-causing events and protect against them.