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Validation of the 3D Physics-Based SEP Forecasting Tool SPARX Using Historical SEP Events

The transport of Solar Energetic Particles (SEPs) through the interplanetary space remains a challenging aspect in space physics. The effects of the interplanetary magnetic field and solar wind turbulence on the SEP arrival to Earth has motivated the adoption of physics-based approaches in operational space weather forecasting. 3D physics-based models offer a framework for incorporating the complexity of SEP transport mechanisms. The forecasting tool, SPARX (Marsh et al. (2015)), employs a relativistic full-orbit test particle approach to simulate SEP propagation to predict their arrival and help assess the potential hazard they may cause. Detection of a solar flare with a magnitude >M1.0 triggers the SPARX system to produce synthetic particle flux profiles from a database of SEP simulations to forecast observations that would be made at 1AU by a spacecraft.

To enhance SPARX's modeling capabilities, we focus here on validating the model through a systematic analysis of recent SEP events. The performance evaluation methodology implemented in Dalla et al. (2018) used a comprehensive list of X-class solar flares between 1997 and 2017 where for every flare, SPARX was operated in forecast mode. The outputs were analysed for SEP event prediction and performance metrics such as Probability of Detection (POD), False Alarm Ratio (FAR) and Critical Success Index (CSI) were calculated. This evaluation methodology will be adapted for events post 2017 to incorporate a larger dataset and thereby enabling a statistically robust validation of the tool. We chose a proton energy threshold of > 20 MeV for maintaining consistency for model evaluation. We present preliminary analysis of SPARX-generated synthetic SEP flux profiles against multi-spacecraft observations from SOLO, SOHO, and STEREO-A, assessing its current efficiency in reproducing key event characteristics such as onset times and intensity profiles. We discuss how these findings guide next-stage improvements in SPARX. This work aims to contribute to bridging the gap between 3D physics-based SEP modeling and real-time forecasting, ultimately advancing our capability to assess and mitigate SEP-driven space weather hazards. Future enhancement consists of incorporating cross-field transport of SEPs and evaluating its impact on SPARX's forecasting accuracy.

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