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Microwave observations for forecasting energetic particles from the Sun

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Solar energetic particles (SEPs), especially protons and heavy ions, are a major space weather hazard when they impact spacecraft and the terrestrial atmosphere. Forecasting schemes have been developed, which use earlier signatures of particle acceleration to predict the arrival of solar protons and ions in the space environment of the Earth. In this study, we investigate the advantages of microwave observations for forecasting the SEP occurrence and SEP energy spectrum. The UMASEP scheme forecasts the occurrence and the importance of a SEP event based on combined observations of soft X-rays, their time derivative, and protons above 10 MeV at geosynchronous orbit. We explore the possibility to replace the derivative of the soft X-ray time history by the microwave time history in the UMASEP scheme.
For the forecast of the SEP energy spectrum, we investigate if the hardness or softness of the proton spectrum in interplanetary space can be predicted from the shape of the microwave spectrum. The technique developed by Chertok et al (2009) is to use the ratio of peak microwave flux densities near 9 and 15 GHz as a predictor. Here, we tested this scheme over solar cycle 23 and 24. A detailed analysis of the results including limitations the methods are presented. We conclude that microwave patrol observations improve SEP forecasting schemes that employ soft X-rays. High-quality microwave data available in real time appear as a significant addition to our ability to predict SEP occurrence and their energy spectrum.
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