Correlating Type II and III Radio Bursts with Solar Energetic Particle Events
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Solar energetic particles (SEPs) are high-energy particles, such as protons, which are accelerated at the Sun and speed outward into the solar system, and if they reach Earth, they can be harmful to satellites, communication systems, and humans in space or on polar airline routes. NOAA defines an SEP event as an occasion when the flux of protons with energies higher than 10 MeV exceeds 10 pfu (particle flux units) as measured by the GOES satellites in geosynchronous orbit. The most intense SEP events are associated with shocks, driven by coronal mass ejections (CMEs), which accelerate particles as they move through the corona. However, very few CMEs result in SEP events. To determine what factors are most important in distinguishing which shock waves will result in SEP acceleration toward Earth, we take into account several variables and perform a principal component analysis to examine their correlations. First, we examine Type II radio bursts, which are caused by electrons accelerating in the same CME-driven shocks that can accelerate SEPs. Using data from the WAVES instrument on the WIND satellite, these Type II radio bursts, as well as the Type III bursts that often accompany them, can be characterized by slope in $1/f$ space and by intensity. In addition, local Langmuir waves detected by WIND, which are caused by electrons speeding through the plasma surrounding the satellite, can be an indicator of the magnetic connectivity between the active region and Earth. Finally, X-ray flares directly preceding the Type II burst are also taken into consideration in the final analysis. Using principal component analysis to determine which of these factors are most relevant to the onset, intensity, and duration of SEP events will be valuable in future work to predict such events.