Persistent Behavior of Low-energy Solar Energetic Particles (SEP) Observed by Parker Solar Probe During Orbit 15 and the Forecasting of SEP events

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Using measures of the persistence of time series, we present a new statistical method for forecasting the arrival time and maximum flux of solar energetic particle (SEP) events. We first discuss the persistent behavior of the SEP time series during SEP events and suggest a method that uses persistence to determine the onset time (OT) of an SEP event. Moreover, the entropy change in a time domain called natural time under time reversal ΔS provides a way to estimate the maximum SEP flux of the ongoing SEP event. Here, we use EPI-Lo data for H^+ below 2 MeV over the whole Orbit 15 from the Integrated Science Investigation of the Sun (IS⊙IS) instrument suite on board NASA's Parker Solar Probe to investigate the broader applicability of these methods. We find that during SEP events the corresponding time series is persistent and we are able to employ the persistence-based OT method to predict SEP events. We find a prediction rate greater than 87.5% (14 out of the 16 SEP events) and a false alarm rate below 2.2%. These values when inserted in the receiver operating characteristics plane indicate that this method is highly statistically significant. Finally, we develop a relationship between the maximum SEP flux and the minimum of ΔS, allowing us to provide a prediction of the future maximum SEP flux during an ongoing event.