



Determining SEP Event Onset Times and Evaluating Their Uncertainty Using a Poisson CUSUM-Bootstrap Hybrid Method

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We are examining a new kind of hybrid method for finding SEP (Solar Energetic Particle) event onset times and assessing their uncertainties. Determining these onset times accurately is important because they are needed to relate the in-situ particle measurements to remote-sensing observations of the associated activity phenomena at the Sun. Only by this, can one identify the actual region and acceleration processes that generated the event. Different methods have been used to determine this onset time; however, the most common ones do not provide reasonable uncertainties so far. The method presented here employs a combination of a statistical quality control scheme, the Poisson-CUSUM (cumulative sum) method, and statistical bootstrapping for calculating a distribution of the necessary parameters for the Poisson-CUSUM method.

The CUSUM method is a statistical quality control scheme, used also in many industries, that is designed to give an early warning when the inspected process or variable changes (Page, 1954). Poisson-CUSUM refers to a specific cumulative sum method that assumes that the monitored variable has a Poisson distribution.

By randomly choosing samples from the particle flux preceding the event, we acquire a distribution of different values for the estimated mean flux and for the standard deviation of the background measurements. These two distributions produce a set of possible onset times via the Poisson-CUSUM method, allowing us to evaluate the uncertainty of an onset time by the precision of our set of candidate onset times, and also to identify the most likely onset time. In addition, we apply the new method to energetic particle observations of the Solar Orbiter spacecraft that come with high energy and time resolution, and perform velocity dispersion analyses.

- S. PAGE, CONTINUOUS INSPECTION SCHEMES, *Biometrika*, Volume 41, Issue 1-2, June 1954, Pages 100–115, <https://doi.org/10.1093/biomet/41.1-2.100>