Statistics of solar energetic particle events: fluences, durations, and time intervals

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The high-energy protons and heavy ions from solar energetic particle (SEP) events present hazard to space systems: damage to science instruments/electronics or to astronauts. A reliable estimate of the high-energy particle environment is very important to assure the mission success. Without it, system survivability is often ensured by setting grossly over-conservative mission requirements, resulting in high mission costs, weight and physically large systems. However, at present our ability to reliably predict the space environments for missions not shielded by planetary magnetic fields is surprisingly poor, especially for missions not at 1 AU. The primary reasons for this are that: (1) SEP events are infrequent and sporadic, (2) statistically valid data exist only at 1 AU, and (3) radial dependence of SEP fluxes and fluences is still to be determined.

Our ultimate goal is to develop an advanced model that can reliably provide statistical estimates of mission-integrated fluences of SEP high-energy protons and heavy ions for arbitrary trajectories, launches on arbitrary future dates, and an improved radial dependence law. This will be achieved by adopting an approach used in a preliminary Solar Probe mission study, that is, by flying a spacecraft through the database (described below) with an appropriate radial dependence law being applied at each time step. While we are still progressing towards the goal, we present here the first results of our study on statistical distributions of event fluences, of event durations, and of time intervals between adjacent events.

For the study, we use the data sets obtained from the instruments onboard the IMP-8 spacecraft. For protons and helium ions, the data from Goddard's Low Energy Detector (LED) and Medium Energy Detector (MED) and the University of Chicago's Cosmic Ray Nuclear Composition (CRNC) telescope were used in the analysis. For heavier ions (CNO and iron ions), only the Chicago instrument provides sufficient data and thus the data from that instrument were used in the study. The data sets cover the period between 1973, day 305, and 1997, day 319, at 1 AU. All the data were averaged over 6-hour intervals and corrected for background by subtracting non-SEP contributions (i.e., contributions from galactic cosmic rays and spurious instrumental effects).

The results obtained for the proton data indicate that: (1) the event fluences can be fit to a log-normal distribution and (2) the distributions of event durations and time intervals between the events follow the Poisson distributions. The complete results will be described in the final manuscript. These distributions will be eventually used to construct a pseudo-data set which will be of great value for our model development.