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A generalized approach to model the spectra and radiation dose rate of solar particle events on the surface of Mars

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For future human missions to Mars, it is important to study the surface radiation environment during extreme and elevated conditions. In the long term, it is mainly Galactic Cosmic Rays (GCRs) modulated by solar activity that contributes to the radiation on the surface of Mars, but intense solar energetic particle (SEP) events may induce acute health effects. Such events may enhance the radiation level significantly and should be detected as immediately as possible to prevent severe damage to humans and equipment. However, the energetic particle environment on the Martian surface is significantly different from that in deep space due to the influence of the Martian atmosphere. Depending on the intensity and shape of the original solar particle spectra as well as particle types, the surface spectra may induce entirely different radiation effects. In order to give immediate and accurate alerts while avoiding unnecessary ones, it is important to model and well understand the atmospheric effect on the incoming SEPs including both protons and helium ions. In this paper, we have developed a generalized approach to quickly model the surface response of any given incoming proton/helium ion spectra and have applied it to a set of historical large solar events thus providing insights into the possible variety of surface radiation environments that may be induced during SEP events. Based on the statistical study of more than 30 significant solar events, we have obtained an empirical model for estimating the surface dose rate directly from the intensities of a power-law SEP spectra.