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## Assessment of F200 fluence for major solar energetic particle events on the multi-millennial time scale

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Solar energetic particle (SEP) fluxes are typically quantified in the F30 units (integrated fluence of particles with energy above 30 MeV) and their direct measurements are available only for the last several decades. On the other hand, a reconstruction of major SEP events in the distant past (centennia-millennia) is possible using data on the cosmogenic isotopes  $^{14}\text{C}$  and  $^{10}\text{Be}$  in stratified and independently datable terrestrial archives (tree trunks or polar ice cores). While such events (or at least candidates) can be identified in the cosmogenic records with a degree of confidence, the estimate of the F30 flux/fluence is ambiguous depending on the proposed SEP energy spectrum. Here we introduce a new index, the integral fluence of an SEP above 200 MeV, F200, which is related to the effective energy of the production of the cosmogenic isotopes by SEP in the Earth atmosphere. This index is robust against the assumptions on the exact shape of the energy spectrum of the event in a wide range of parameters. Using several records of cosmogenic isotopes, we present a reconstruction of the F200 fluence for major SEP events in the past, and also assess the occurrence probability density function for extreme events. In particular, we evaluate that extreme SPEs with  $F200 > 10^{10} \text{ cm}^{-2}$  may occur no more frequently than once per 10 000 years or even rarer up to never.

### Collaboration

– not specified –

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