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Signatures of cosmic-ray increase attributed to exceptional solar storms inferred from multiple cosmogenic radionuclide records

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Miyake et al. (2012, 2013) discovered rapid increases of ^{14}C content in tree rings dated to AD 774-5 and AD 993-4 which they have attributed to cosmic-ray events. These extreme particle events have no counterparts in the instrumental record and have been tentatively associated with solar proton events, supernovae and short gamma-ray bursts, which have very different energy spectra. Cosmogenic radionuclides such as ^{14}C, ^{10}Be and ^{36}Cl arise from the interaction of cosmic rays with atmospheric nitrogen, oxygen and argon. These radio-isotopes are produced through different reaction pathways and vary with different energy dependencies of the production rate cross section. Owing to this, yield functions can be used to determine the energy level of incident particles. However, only ^{14}C has been measured at high resolution to quantify the energy and thus the origin of the outbursts. We present an annually resolved record of ^{10}Be from the NGRIP ice core for the two events. In addition, we also utilized the GRIP ice core ^{36}Cl record in our analysis.

Our results show that the differential production of cosmogenic ^{14}C, ^{10}Be and ^{36}Cl is consistent with a solar energy spectrum. Considering the notable increase in radionuclides, the solar storms would have had to be substantially greater than the largest recorded geomagnetic storm, the so-called Carrington event. This challenges our understanding of the sun's dynamics. Furthermore, the events could possibly be of interest for the investigation of potential cosmic ray-cloud linkages (Svensmark & Friis-Christensen, 1997). Alternatively, such outbursts of energetic particles have the potential to deplete atmospheric ozone and alter atmospheric circulation. Ultimately, the magnitude of such particle events draws attention to the perhaps underestimated potential of the sun to cause great damage to modern technologies.

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