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Extreme Solar Particle Storms: How hostile can the Sun be?

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It is recognized now that strong sporadic events (called solar particle storms) with high fluxes of solar energetic particles (SEP) produced during eruptive solar flares and coronal mass ejections form a serious issue for Space Weather and pose deadly hazards for technological devices and even human lives outside the protective Earth's atmosphere and magnetosphere. The strongest directly observed solar particle storm took place on 23-Feb-1956 with a 50-x enhancement over the galactic background as recorded on the ground. Can stronger storms appear? How often? Can we assess the "worst case scenario"? Knowing answers to these questions is of great importance, not only purely academic but also societal and technological. The era of direct measurements of SEP events by space-borne detectors covers 40-50 years, and by ground-based instruments about 70 years. Because of the limited dataset we possess, these questions can be answered only using indirect methods. An overview of different method is presented here with a search for extreme SEP events.

First we discuss the method of cosmogenic radionuclides (^{14}C, ^{10}Be, ^{36}Cl) measured in independently dateable natural archives, that forms a reliable proxy of cosmic ray variability on the centennial-millennial time scale. So far, three extreme SEP events have been identified during the Holocene: the strongest known event of 775 AD, which was a factor 40-50 stronger than that of 23-Feb-1956, and a couple of slightly weaker event of 994 AD an 3372 BC. Next we discuss the method of cosmogenic isotopes (primarily ^{26}Al) measured in lunar rocks, which does not allow to identify individual events but provides evaluation of the mean flux of SEP over a million of years. We also critically discuss a statistical study of the large ensemble of sun-like stars, some of which exhibit super-flares.

Considering all data in their diversity and recent achievements in this field, we argue that the event of 775 AD may serve as the worst case scenario of an extreme solar particle storm, and that we do not expect much stronger events on the megayear timescale.