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Long term trends in solar energetic particle events

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Society is increasingly reliant on systems which are vulnerable to Space Weather. Solar energetic particle events are an important aspect of space weather, being particularly damaging to space-borne systems and posing a significant health hazard to astronauts and crews and passengers in aircraft at high latitudes and high altitude. To help quantify our vulnerability to SEP events, various statistical models have been developed which predict quantities such as the peak energetic particle flux in an event, or fluence over a given interval. Generally these models are developed using direct observations of energetic particle fluxes measured on a range of satellite missions since the start of the space age. Reconstructions of solar activity from cosmogenic isotope and geomagnetic activity records show that the space age has coincided with a period of unusually high solar activity, called a grand solar maximum (GSM). However observations of the long and deep minima of solar cycle 23, and the progression of solar cycle 24 have led to predictions that the sun is currently exiting this GSM and probably entering a significantly quieter period of activity. Given these predictions, should we also expect a corresponding variation in the occurrence and severity of SEP events? By using an $\sim$400 year database of very large SEP events determined from the analysis of nitrates in polar ice cores and reconstructions of past solar activity, we present results that suggest a return to more moderate levels of solar activity will enhance the probability of observing very large SEP events. There are uncertainties and some debate about the ice core events; however, additional analysis of a homogenised space age (40 year) database of SEP events also supports the hypothesis that a return to more moderate levels of solar activity will probably lead to a decrease in the event occurrence frequency, but an increase in the average event fluence. Consequently large events such as the "Carrington flare" may become more likely at more average levels of solar activity, with obvious implications for statistical SEP models based on modern data which are largely taken with a GSM.