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No nitrate spikes detectable in several polar ice cores following the largest known solar events

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Solar energetic particle (SEP) events are a genuine and recognized threat to our modern society which is increasingly relying on satellites and technological infrastructures. However, knowledge on the frequency and on the upper limit of the intensity of major solar storms is largely limited by the relatively short direct observation period.
In an effort to extend the observation period and because atmospheric ionization induced by solar particles can lead to the production of odd nitrogen, spikes in the nitrate content of ice cores have been tentatively used to reconstruct both the occurrence and intensity of past SEP events. Yet the reliability of its use as such a proxy has been long debated. This is partly due to differing chemistry-climate model outputs, equivocal detection of nitrate spikes in single ice cores for single events, and possible alternative sources to explain nitrate spikes in ice cores.
Here we present nitrate measurements from several Antarctic and Greenland ice cores for time periods covering the largest known solar events. More specifically, we use new highly-resolved nitrate and biomass burning proxy species data (e.g. black carbon) from continuous flow analysis following the largest known solar events from the paleo record – the SEP events of 775 and 994 AD. We also consider the historical Carrington event of 1859 as well as contemporary events from the past 60 years which were observed by satellites. Doing so we show that i) there are no reproducible nitrate spikes in Greenland and Antarctic ice cores following any of these major events and that ii) most nitrate spikes found in ice cores are related to biomass burning plumes.
Our analysis thus suggests that ice-core nitrate data is not a reliable proxy for atmospheric ionization by SEP events. In light of our results, we advocate that nitrate spikes so far identified from single ice cores should not be used to assess the intensity and occurrence rate of extreme solar events.