Exploring Extreme Solar Proton Events, Their Possible Atmospheric Impacts, and Potential Paleoclimate Signatures

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Satellite measurements and global modeling efforts have established the significant impact of solar energetic particles on the chemistry and dynamics of Earth's upper atmosphere. However, determining the magnitude and frequency of solar energetic particle events throughout Earth's history remains elusive. The analysis of paleoclimate archives of cosmogenic signatures in tree rings and ice cores holds much promise, but distinguishing solar influences from atmospheric effects is challenging. We present a series of WACCM (CESM) modeling experiments that consider the potential impact of extreme solar proton events (SPEs) on the atmosphere, including events much stronger than the SPEs observed to date. Comparisons between model simulations of recent SPEs and surface snow observations at Greenland fail to support the use of nitrate spikes in ice cores to identify individual SPE events, motivating the search for alternate proxies. We examine the largest SPE measured by satellite (October 1989) and calculate its possible atmospheric impact had it occurred during ideal polar meteorological conditions. Using preliminary results from coupled EPREM-WACCM model simulations, we study the effect that the July 2012 SPE would have on the atmosphere if its maximum intensity reached Earth. We also conduct simulations based on estimates of SPE energies needed to explain the 14C tree ring enhancements of AD 774 to 775 and place results in the context of limits of solar flares in sun-like stars, contributing toward efforts to detect solar footprints in paleoclimate archives amid variability attributable to the Earth system.