



## **The Causes of the Little Ice Age**

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Both external forcing (solar radiation, volcanic eruptions) and internal fluctuations have been proposed to explain such multi-centennial perturbations as the Little Ice Age. Confidence in these hypotheses is limited due to the limited number of proxies, as well as only one observed realization of the Last Millennium. Here, we evaluate different hypotheses on the origin of Little Ice Age-like anomalies, focusing in particular on the long-term response of North Atlantic and Arctic climate perturbations to solar and volcanic perturbations. For that, we conduct a range of sensitivity tests carried out with the Community Earth System Model at the National Center for Atmospheric Research, focusing in particular on the sensitivity to initial conditions and the strength of solar and volcanic forcing. By comparing the climate response to various combinations of external perturbations, we demonstrate nonlinear interactions that are necessary to explain trends observed in the fully coupled system and discuss physical mechanisms through which these external forcings can trigger multidecadal modes of the Atlantic Multidecadal Oscillation and subsequently lead to a Little-Ice-Age-like regime. For that, we capture and compare patterns of the coupled atmosphere-sea-ice-ocean response as revealed through a range of data analysis techniques. We show that the large 1257 Samalas, 1452 Kuwae, and 1600 Huaynaputina volcanic eruptions were the main causes of the multi-centennial glaciation associated with the Little Ice Age.