Combining Earth System Modeling and Machine Learning to Investigate Volcanic Sulfate Deposition in Polar Ice Cores

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Volcanic eruptions emit large amounts of sulfur dioxide (SO_2), water, and other chemicals into the atmosphere, both in the troposphere and the stratosphere. Most of the SO_2 is converted to sulfate aerosol, which is eventually deposited following long-range transport. The deposits from large eruptions are potentially detectable in ice cores, but there are many cases in which sulfate layers have not been linked to their source volcanoes. As volcanoes can act as significant shocks to the global climate system, we are interested in locating these eruptions in order to increase understanding of the volcanic record. To narrow down the search, we performed 140 simulations of volcanic eruptions using the GISS ModelE Earth system model. We varied the latitude, longitude, Julian day, plume top, plume bottom, and injected SO_2 and H_2O amounts using a Latin hypercube sampling approach, and analyzed correlations between these parameters and sulfate depositions at ice core sites in Antarctica and Greenland. Using machine learning and parameter estimation, we generated probability distributions and maximum likelihood estimates for the parameters given sulfate deposition data, which can predict latitude with some skill. We find that the volcano latitude and SO_2 content are best correlated with sulfate depositions at each pole, while longitude, julian day, and H_2O have small or insignificant effects. Plume altitude and thickness are important because they determine how much of the SO_2 is injected into the stratosphere, which has implications for sulfur transport and lifetimes.