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Volcanic Eruptions and Climate: Outstanding Research Issues

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Large volcanic eruptions inject sulfur gases into the stratosphere, which convert to sulfate aerosols with an e-folding residence time of about one year. The radiative and chemical effects of this aerosol cloud produce responses in the climate system. Based on observations after major eruptions of the past and experiments with numerical models of the climate system, we understand much about their climatic impact, but there are also a number of unanswered questions. Volcanic eruptions produce global cooling, and are an important natural cause of interannual, interdecadal, and even centennial-scale climate change. One of the most interesting volcanic effects is the "winter warming" of Northern Hemisphere continents following major tropical eruptions. During the winter in the Northern Hemisphere following every large tropical eruption of the past century, surface air temperatures over North America, Europe, and East Asia were warmer than normal, while they were colder over Greenland and the Middle East. This pattern and the coincident atmospheric circulation correspond to the positive phase of the Arctic Oscillation. While this response is observed after recent major eruptions, most state-of-the-art climate models have trouble simulating winter warming. Why? High latitude eruptions in the Northern Hemisphere, while also producing global cooling, do not have the same impact on atmospheric dynamics. Both tropical and high latitude eruptions can weaken the Indian and African summer monsoon, and the effects can be seen in past records of flow in the Nile and Niger Rivers. Since the Mt. Pinatubo eruption in the Philippines in 1991, there have been no large eruptions that affected climate, but the cumulative effects of small eruptions over the past decade have had a small effect on global temperature trends. Some important outstanding research questions include: How much seasonal, annual, and decadal predictability is possible following a large volcanic eruption? Do volcanic eruptions change the probability of El Niño or La Niña in the years following the eruption? Are there decadal-scale oceanic responses that can provide long-term predictability? What was the contribution of volcanic eruptions to initiation and maintenance of the Little Ice Age? What are the observational needs for future volcanic eruptions that will help to improve forecasts, observe responses following volcanic eruptions, and better understand nucleation and growth of sulfate aerosols, which is important for evaluating suggestions for considering anthropogenic stratospheric clouds for climate engineering?