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Understanding the tempo and environmental effects of LIP CO_2 and SO_2 emissions

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Large igneous provinces (LIPs) are associated with severe environmental effects, including mass extinctions and oceanic anoxic events. LIPs affect the environment through their gas emissions, including CO_2 and SO_2. Volcanic CO_2 is a greenhouse gas with a long residence time in the ocean-atmosphere system, leading to warming on long timescales. Volcanic SO_2 (oxidized to sulfate aerosols) causes climate cooling and has an atmospheric residence time of months to years. Following our understanding of modern large eruptions (e.g., Pinatubo), the environmental effects of volcanic sulfate are thought to be short-lived (years to tens of years) and persist only for the duration of individual eruptions. Typically, these "cold-snaps" are thought to be superimposed onto longer-term CO_2-driven warming, without substantial longer-term interaction. However, the dynamics of these cooling events and their effects on the Earth system remain uncertain. These years to a few-thousand-year timescales are critical for organisms and for climate-regulating processes such as deep ocean mixing.

We will discuss a range of proxy constraints on LIP gas emission tempos, including volcanology, geochronology, and sedimentary proxies such as mercury. Mercury records, in particular, provide a unique set of high-resolution constraints on LIP degassing. We will present results from multiple LIPs with estimates of the typical duration and eruption recurrence timescales. These different constraints all suggest individual eruptions potentially lasted, and hence caused cooling events, of 100s to ~1000 years.

We used a biogeochemical box model to test whether the effects of LIP sulfur emissions are simply additive to the impact of carbon alone. Contrary to assumptions, we found that LIP SO_2 emissions significantly impact the longer-term carbon cycle. In particular, the strongly temperature-dependent equilibrium coefficients for marine carbonate chemistry mean that climate cooling leads to faster transport of atmospheric carbon into the ocean, causing changes in the CCD and pH. The few thousand-year timescale for ocean overturning circulation leads to carbon-cycle effects that persist substantially longer than the cooling event itself. We will discuss the ability of proxy records to resolve these events and improve understanding of the environmental and carbon cycle effects of LIP CO_2 and sulfur emissions.