Self-limiting chemistry, aerosol and climate effects of large-scale flood basalt eruptions

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Flood basalt volcanism is typified by repeated effusion of huge batches of magma (about 1000 cubic km) in events lasting more than 5-15 years. Estimated mean eruption rates for these events are 10-100 million kg per sec. It would take 10 years of continuous activity at Laki 1783-1784 AD peak eruption rate (12 million kg per sec) to produce a lava flow field of flood basalt dimensions. Model estimates indicate fountain heights of more than 1 km and plume heights of 10-15 km. A typical flood basalt event releases about 10,000 million tons of sulfur dioxide into the atmosphere or 1000 million tons per year for a 10-year-long event. We use a state-of-the-art global aerosol microphysics model (GLOMAP) to simulate the atmospheric and climatic effects of large-scale flood basalt eruptions. Our standard eruption scenario is that of the Laki eruption, which injected around 100 million tons of sulfur dioxide into the upper troposphere/lower stratosphere over the course of eight months. Our GLOMAP aerosol model results for Laki compare well with volcanological and historical records and other modelling studies. Subsequently, we scaled the Laki standard scenario by factors of 10 and 100 for the amount of sulfur dioxide released. In addition we conducted series of model simulations in which several consecutive Laki eruptions, or their scaled equivalents, are simulated for up to ten years. We assume that the sulfur-release by one Laki x10 per year for ten years corresponds to a typical flood basalt eruption, such as the 14.7 Ma Roza Member of the Columbia River Basalt Group. Furthermore, sensitivity runs were carried out by changing the eruption location and introducing volcanically quiescent periods to quantify atmospheric recovery times. Our modelling results imply that the sulfate aerosol lifetime is quasi equal across the eruption scenarios no matter how much volcanic sulfur dioxide was injected. In sharp contrast, the sulfur dioxide lifetime increases significantly (albeit non-linearly) with increasing atmospheric sulfur-loading. Quantification of both the chemical and the aerosol microphysical processes driving these self-limiting effects also shows that the efficiency to form new particles drops with increasing sulfur-loading. This implies that climatic effects of flood basalt eruptions should not scale linearly with the amount of sulfur dioxide released. We will discuss these aerosol-chemistry-climate feedback mechanisms and the magnitude of the climatic effects as well as the potential environmental consequences.