

# Atmospheric Processing, Environmental Effects, and Climate Change: on the Role of Climate Signaling by Volcanic Sulphate and Volcanic Ash vs Mineral Dust

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There is widespread consensus that volcanic sulphate aerosols in the stratosphere can restrict solar energy reaching the earth's surface for years, so reducing surface temperatures, modifying global circulation patterns, and generally changing the global climate system. Global climate models struggle to replicate the observed variability of the earth system after massive volcanic eruptions up to this point, and the reaction of the climate system to large volcanic eruptions is not fully understood. For geological periods, it has been proposed that volcanic ash influences climate change: on the Role of Climate Signaling by Volcanic Sulphate and Volcanic Ash vs Mineral Dust. *J Ecol Toxicol*, 6: 134.

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Effects of volcanoes on the climate, for instance, are covered in a number of earlier reviews. All of these studies, however, concentrate on the impact of volcanic sulphate aerosols on the climate. According to, the climatic effects of volcanic ash and tephra are quite minor and only last as long as these particles are present in the atmosphere. Volcanic ash, as opposed to volcanic gases and aerosols, leaves the atmosphere more quickly following an eruption [3]. Following large volcanic eruptions, only submicron volcanic ash particles have been seen for several months in the lower stratosphere. The enormous atmospheric load of volcanic ash near to the source region may have an impact on the amplitude of the diurnal cycle of surface air temperature over a period of up to a few weeks. Do not, however, disregard the effect that volcanic ash has on the biogeochemistry of the ocean; volcanic ash may activate the "biological pump," a mechanism that converts CO<sub>2</sub> to organic carbon and permits organic matter particles to sink to the deep ocean, reducing atmospheric CO<sub>2</sub>. Recent studies have demonstrated that volcanic eruptions' airborne debris, particularly volcanic ash, alters the biogeochemical processes in the surface ocean, directly in

climate [4]. Before the eruption of the Kasatochi volcano in the Aleutian Islands in August 2008, these dynamics were, however, generally ignored by the community of volcano-climate researchers. Following this eruption, the NE Pacific's favourable atmospheric and oceanic conditions allowed for the production of a massive phytoplankton bloom, which was seen across a vast area by satellite sensors, in situ observations, and modelling studies. The first time that volcanic ash was effectively used to fertilise the ocean's surface, this event proved that it could do so and potentially alter the climate. Volcanic ash can consequently function similarly to mineral dust, which is frequently believed to be the primary external source of iron for the open ocean.

In this time, the report the climatic impacts of volcanic ash to those of volcanic sulphate and sheds new information on how volcanic eruptions affect the climate. The study intends to spark fresh debates and collaborative, interdisciplinary research initiatives among communities of researchers with expertise in ocean biogeochemistry and biology, volcanology, geochemistry, meteorology, atmospheric chemistry, and climate [5]. Even in the age of anthropogenic climate change, a better comprehension of natural climate change drivers, such as volcanic eruptions, is essential for interpreting natural climatic variability. The fate of volcanic ash and sulphate is discussed in the

determined by remote sensing methods. The melt droplets that are part of the magma and are analysed to determine the pre-eruptive sulphur content do not take into account any chemical conversion that occurs during the eruptive phase, so the petrological data provide a minimal estimate of the sulphur that was erupted.

### **Chemical and Mechanical Processing in Volcanic Plumes**

The volume above the vent that is up to the point of neutral buoyancy, which is indicated by the predominant upward motion, is referred to as the volcanic eruption plume. By entraining ambient atmospheric water vapour into the plume and creating buoyancy, turbulent motion dilutes the gas-particle mixture emitted from the vent. Energy in the plume of a volcanic eruption is also redistributed changes in the state of water aggregation. Volcanic ash and gases cool in this volume from around 1000°C to less than 0°C in just a few minutes, and significant volcanic ash fragmentation processes take place. The parameters of the eruption have a significant impact on the size distribution of volcanic ash.

According to, H<sub>2</sub>S oxidation can occur at the hot core ( $T > 600^{\circ}\text{C}$ ) of a volcanic plume, which is where SO<sub>2</sub> injection into the atmosphere can occur. However, H<sub>2</sub>S oxidation is not primarily produced directly from shallow or deep magma systems. The heated core of volcanic plumes is thought to be the primary factor causing variations in sulphur speciation. It is shown that the redox status of magma as measured at depth does not always correspond to that of its rising gases. Depending on the initial state of oxidation, the heated core of a volcanic plume can act as a reactor for SO<sub>2</sub> synthesis and transform an originally SO<sub>2</sub>-poor mixture into a SO<sub>2</sub>-rich mixture. Consequently, these investigations offer yet another justification for the variations in atmospheric SO<sub>2</sub> measurements following volcanic eruptions. The dew point for sulfuric acid in the eruption plume was estimated to be 338°C due to further chemical transformations of sulphur-containing gases and particles in the mid- and low-temperature zones of volcanic plumes. However, because this dew point temperature only applies to very high sulphuric acid concentrations at atmospheric pressure, it is only partially a reliable estimate for volcanic plumes. It is shown that  $T = 150^{\circ}\text{C}$  and  $50^{\circ}\text{C}$  are more accurate predictions for the dew points of volcanic plumes of sulphuric acid and water, respectively. At  $T = 150^{\circ}\text{C}$ , when sulphuric acid condensation begins, the concentration of sulphuric acid droplets rises until it reaches a plateau at a temperature just below  $50^{\circ}\text{C}$ .

### **Atmospheric Burden, Residence Time, and Deposition**

In terms of space and time, volcanic activity, the location of an eruption, and the patterns of atmospheric dispersion upwind from the volcano all influence the atmospheric concentrations of volcanic ash and sulphate. From daily mean near-surface concentrations of 400 g/m<sup>3</sup> in Scandinavia to maximum ash concentrations of roughly 4000 g/m<sup>3</sup> in the volcanic ash cloud transported over Europe, volcanic ash mass concentrations measured in the troposphere during the eruption of Iceland in 2010 varied. In Iceland, the daily average near surface concentration during the active eruption and also subsequently during resuspension events approached 1000 g/m<sup>3</sup>. Detailed information on the resuspension of volcanic ash following different volcanic eruptions is available here.

A sulphate aerosol layer was found in the lower stratosphere in undisturbed conditions, with a global sulphate load of about 0.15 Tg Sulfur. Over a few years, volcanic sulphate aerosols greatly increase this stratospheric background sulphate concentration. Approximately one year passes during the e-folding decay of stratospheric sulphate. Particles of SO<sub>2</sub> and sulphate are widely advected around the world

after being introduced or generated in the stratosphere. Sulphate aerosols circled the globe two weeks after the Krakatau eruption in 1883.

### **Climate Forcing**

During volcanic eruptions or remobilization events, volcanic ash is discharged into the atmosphere, which lowers visibility and solar irradiation reaching the earth's surface and cools the surface. The majority of volcanic ash has a short atmospheric residence time, which limits its direct radiative impacts to the vicinity of the eruption and

The term "emission" refers to the discharge of material into the atmosphere from a location outside the atmosphere, which serves as the atmosphere's source. Mineral dust source sites are typically found in semiarid or arid regions with minimal vegetation and dry surfaces. The wind can gather and move fine-grained particles into the atmosphere in this area. The areas where dust emission occurs are often defined by numerical models for mineral dust mobilisation based on factors including soil moisture, soil texture, and vegetation influences. The emission of mineral dust into the atmosphere is a complex, nonlinear function of both the soil surface qualities and the weather (wind friction velocity and precipitation). When the wind friction velocity surpasses a certain threshold, mineral dust emissions happen from an erodible surface. During explosive volcanic eruptions, phreatomagmatic eruptions, or pyroclastic density currents, volcanic ash is produced. Around 20 volcanoes erupt on average per hour around the planet, 50–70 volcanoes erupt annually, and at least one big eruption with a Volcanic Explosivity Index of at least 4 occurs each year. When assuming a particle density of 2000 kg/m<sup>3</sup>, the total annual emissions of volcanic ash into the troposphere by modest volcanic

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discussed in the literature, including volcanism, orbital changes, silicate weathering in orogens, changes in cosmic ray fluxes, and tectonic motion. Recently, the topic of volcanic forcing on weather on geologic periods has expanded to include additional indirect impacts as well as the radiative effects of stratosphere sulphate. Despite the fact that the presence of volcanic glass in deep-sea rocks has been recognised as a sign of volcanic activity, ocean fertilisation by volcanic ash was not thought to be a factor in millennium climate change.

It is currently unknown, though, whether even a mega-volcanic eruption could bring about climatic cooling on a timescale of at least a

increased collaboration among the scientific community looking into the atmospheric chemical effects and changes of volcanic ash and mineral dust. Model parameters for the remobilization of volcanic ash from its land-based deposits are based on techniques for mobilising mineral dust. However, due to the restricted availability of ash in its deposits, updated techniques will be required taking into account mass conserving parameterizations, where the movement of deposits is also included. Researchers who study mineral dust may also be interested in these parameterizations.

It has been difficult to gain a comprehensive knowledge of the crucial processes up to now because of the harsh circumstances for multiphase chemistry found in volcanic plumes with regard to temperature and its gradients, acidity, lightning, and particle load. Despite these challenges, multiphase volcanic plume chemistry offers the potential to shed light on mechanisms that may be crucial for mineral dust atmospheric chemical processing under less extreme settings. The production of bioavailable iron on volcanic ash and mineral dust surfaces for ocean fertilisation is particularly highlighted in this study. Our imperfect understanding, especially from leaching studies, might be significantly increased through collaborative experimental and modelling research efforts involving mineral dust and volcanic ash experts. Even while leaching experiments are crucial to our current understanding, they may become even more crucial if uniform methods were established and followed. This would enable comparisons to be made between studies carried out at various laboratories. Additionally, as tiny particles are prone to long-distance transmission, particle size distributions and mineralogy for diameters significantly lower than 2  $\mu\text{m}$  should be extensively explored. This is especially true for volcanological researchers.

In order to more accurately analyse the climate effects of volcanic ash vs mineral dust during the geological past, from terrestrial and

marine environmental archives, including ice, peat, sea, and ocean sediment cores for mineral dust and volcanic ash deposition, must be put together. However, until we have a thorough grasp of current processes, we won't be able to effectively address these processes in the palaeo-records or with regard to the potential effects of mineral dust on the climate in the future, as opposed to volcanic ash.

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## Conflicts of Interest

The author has no known conflict of interest associated with this paper.

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