Environmental and Climatic Effects of Atmospheric Processing of Volcanic Ash vs Mineral Dust

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Abstract

This article compares volcanic ash and mineral dust in terms of their sources, atmospheric loads, deposition mechanisms, atmospheric processing, and efects on the environment and climate. It also compares their chemical and physical properties. Although there are signifcant diferences between the histories of volcanic ash and mineral dust particles before they are released into the atmosphere, there are many similarities between how the atmosphere is processed at ambient temperatures and the efects on the environment and climate. This review paper seeks to encourage future combined research methods to advance our existing understanding through close collaboration between mineral dust and volcanic ash experts by outlining the similarities and contrasts between the processes and consequences of volcanic ash and mineral dust.

[illegible]: Volcanic; Dust

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Volcanic eruptions produce a signi cant amount of volcanic ash. It is created by volcanic vents' surrounding rock material and magma fragmenting throughout the formation process. According to the intensity of a volcanic eruption, volcanic ash is ejected into the free troposphere or even the stratosphere, where it is carried by the dominant winds until it is eliminated from the atmosphere by gravity settling and wet deposition [1]. According to wind speed, ash size, ash density, and eruption magnitude, volcanic ash is also known to be mobilised by wind from its deposits, which have accumulated a er volcanic eruptions on land along the main transport directions of the volcanic cloud, which extends over hundreds to thousands of kilometres [2]. Unlike the mineral dust in the atmosphere, numerous studies have been conducted on the global cycle of mineral dust and how it a ects the Earth's climate [3]. By serving as cloud condensation or ice nuclei, mineral dust particles have an impact on the radiative forcing of the atmosphere both directly and indirectly [4]. Climate variability impacts the mineral dust load of the atmosphere through changes in precipitation, vegetation cover, and wind. In addition, mineral dust aerosols regulate ozone photochemistry and provide nutrients to marine and terrestrial ecosystems [5].

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According to the "Glossary of Atmospheric Chemistry Terms," dust is made up of small, solid, dry particles that are discharged into the atmosphere by mechanical or arti cial operations as well as by natural factors like wind and volcanic eruptions (e.g., crushing, milling, and shoveling). Typically, dust particles range in size from 1 to 100 m and descend slowly from the atmosphere due to gravity. Mineral dust and volcanic ash may thus make up a small portion of all dust that has been seen [6]. e following criteria are used to di erentiate between mineral dust and volcanic ash: While volcanic ash is a loose, unconsolidated substance with smaller particle sizes, atmospheric mineral dust is derived from a suspension of soil minerals. Silica and oxygen, which are the primary ingredients of minerals and rocks in the Earth's crust and mantle, are found in large quantities in volcanic ash as well as in mineral dust [7]. e magma from which the volcanic ash is formed largely determines the chemical makeup of the bulk material. ree distinct forms of magma are typically used to separate them. Di erent viscosities, melting points, and typical volatile concentrations are present in these varieties of magma. Silica makes up between 45 and 75 weight percent of the mineral content of volcanic ash. Additionally, silicate makes up the majority of minerals, including

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as the atmosphere's source. Mineral dust source sites are typically found in semiarid or arid regions with minimal vegetation and dry surfaces. e wind can gather and move ne-grained particles into the atmosphere in this area. In most cases, dust emission zones are determined by numerical models for mineral dust mobilisation using factors including soil moisture, soil texture, and vegetation in uences. e emission of mineral dust into the atmosphere is a complicated, nonlinear function of both the soil surface qualities and the weather. Mineral dust emissions from an erodible surface occur when the wind friction velocity exceeds a threshold value, dependent on the soil properties. Explosive volcanic eruptions, phreatomagmatic eruptions, or pyroclastic density currents all produce volcanic ash. Around 20 volcanoes erupt worldwide at any given time, 50–70 volcanoes erupt annually, and at least one big eruption with a Volcanic Explosivity Index of at least 4 takes place each year. Small volcanic eruptions with VEI 4 account for the majority of eruptions, and their combined emissions of volcanic ash into the troposphere are estimated to be 20 Tg/yr, or 10 km3, assuming a particle density of 2000 kg/m3. ese volcanic ash emissions, however, are o en quickly evacuated from the atmosphere and only have local signi cance in the region of the volcanoes up to a radius of around 100 kilometres.

ere is a lot of temporal and spatial variation in the concentrations of volcanic ash and mineral dust in the atmosphere. Mineral dust load in the atmosphere is largely in uenced by seasonal uctuation, such as rainy and dry seasons, whereas volcanic ash load is primarily in uenced by the occurrence of sporadic and typically unpredictable volcanic

If there are more aerosols available to act as cloud condensation nuclei, then a greater number of cloud droplets are created, o en with smaller sizes. High concentrations of cloud droplets slow the formation of di usional droplets. As a outcoming, droplet sizes needed for e ective growth through droplet collision cannot be attained. erefore, modi cations to CDNC can have an impact on cloud albedo, cloud duration, and precipitation generation. In the tropics, it is particularly important to alter how precipitation forms in deep convective clouds. Precipitation may be sti ed as a nding of the local in uence near the aerosol source regions [15]. However, as more liquid water and water vapour remain in the sky, precipitation will occur elsewhere, increasing the likelihood of erosion and ooding. Another external source of iron that is usually ignored is the oceanic deposition of volcanic ash. Its relevance and in uence on the climate, however, have long been seen as insigni cant. It is generally accepted that the main climate-changing impact of volcanic eruptions outcomes from the reduction of solar radiation caused by volcanic sulphate aerosols. Volcanic ash, as opposed to volcanic gases and aerosols, leaves the atmosphere signi cantly more quickly following an eruption. Recent research has however demonstrated that volcanic ash changes the biogeochemical processes in the surface ocean, directly altering climate. Volcanic ash carried by the air may release trace species when it comes into contact with seawater and settles on the ocean's surface. us, volcanic ash, despite its intermittent discharge, may function similarly to mineral dust.

[illegible]

Mineral dust and volcanic ash particles have very di erent histories before they are released into the atmosphere, but they also have a lot in common when it comes to how the atmosphere is processed at ambient temperatures and how it a ects the environment and the climate. erefore, the goal of this review is to encourage increased collaboration among the scienti c community looking into the atmospheric chemical e ects and changes of volcanic ash and mineral dust. Model parameterizations for the mobilisation of mineral dust from on-land deposits of volcanic ash are based on these techniques. Due to the restricted availability of ash in its deposits, new techniques will be required to take into account mass conserving parameterizations, where the movement of deposits is also taken into account. Researchers who study mineral dust may also be interested in such parameterizations. An di culty that has prevented a comprehensive understanding of the critical processes up to this point is the extraordinary circumstances for multiphase chemistry present in volcanic plumes with regard to temperature and the gradients associated with it, acidity, lightning, and particle load. Despite these challenges, the multiphase chemistry of volcanic plumes under extreme conditions o ers the potential to shed light on mechanisms that may be crucial for mineral dust atmospheric chemical processing under less extreme circumstances. e production of bioavailable iron on mineral dust and volcanic ash surfaces for ocean fertilisation is highlighted in this article in particular. Especially from leaching trials, collaborative experimental and modelling research initiatives between mineral dust and volcanic ash researchers could signi cantly advance our current, insu cient understanding. In order to better understand the processes a ected by freezing temperatures, such as IN formations or Fe mobilisation, and their e ects on the climate, more systematic research should be done. During volcanic eruptions, ash particles are easily injected into atmospheric regimes where freezing temperatures are prevalent. Wet deposition of volcanic ash and mineral dust from the atmosphere is associated with the creation of CCN and IN. In terms of volcanic ash, there is an urgent need for better understanding of aggregation, a deposition process that reduces the amount of ash for long-range transport. All ash dispersion models don't adequately account for this phenomenon. a collaboration between the meteorological and volcanic communities to understand the basic principles of ash aggregation.

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To more accurately analyse the climate impacts of volcanic ash vs mineral dust during the geological past, sediment cores from ice, peat, sea, and ocean sediments for mineral dust and volcanic ash deposition must be constructed for paleoclimate. However, until we have a thorough grasp of current processes, we won't be able to e ectively address these processes in the palaeo-records or with regard to the potential e ects of mineral dust on the climate in the future, as opposed to volcanic ash.

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