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Modeling the impact of carbon and sulfur emissions from end-Triassic volcanism

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Empirical evidence suggests that pulsed volcanic activity of the Central Atlantic Magmatic Province (CAMP) severely perturbed Earth's climate and biogeochemical cycles at the Triassic-Jurassic boundary approximately 201 million years ago. Studying the impact of such drastic events can provide important insight into Earth-system sensitivity and resilience. Here, we present novel model results on the end-Triassic climate and marine biogeochemistry as well as the potential impact of volcanogenic carbon and sulfur emissions.

An ensemble of possible late Triassic pre-eruption equilibrium states has been simulated for different concentrations of atmospheric carbon dioxide and configurations of Earth's orbit. The simulated late-Triassic climate states are in good agreement with proxy data and earlier modeling studies. The unique shape of the supercontinent Pangaea decisively influences the climate: Westward transport of warm water in the Panthalassa ocean results in more abundant rainfall and higher temperatures in eastern central Pangaea. The monsoonal precipitation is found to depend on the precession angle of Earths orbit.

To investigate the effects of volcanic eruptions, transient changes in climate and marine biogeochemistry have been simulated for an ensemble of perturbations reflecting the combined effects of volcanic carbon emission and sulfate aerosols. For example, the simultaneous emission of 5300 GtC and a stratospheric injection of 50 GtS within approximately 1200 years changes the global mean temperature by $-8°C$ in the coldest century before a peak global warming of +3°C is reached. This sequence of cooling and warming would presumably exert exceptional environmental stress on ecosystems and could also relate to sea-level fluctuations recorded by geologic proxies. In more prolonged emission scenarios, the cooling effect and the simulated Carbon Isotopic Excursion (CIE) diminish. Regarding the three debated drivers of the marine extinction, temperature increase, anoxia and acidification, we find for the examined scenarios that (1) sea surface temperatures in the tropics change significantly less than on global average, (2) anoxia does not expand significantly although the overturning circulation weakens under global warming, and (3) the reduction of carbonate saturation is most pronounced in the Tethys Sea, where most Triassic coral reefs have been found.