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Impact of volcanic eruptions on the marine carbon cycle

Joachim Segschneider (1), Niemeier Ulrike (1), Wiesner Martin (2), and Timmreck Claudia (1)

(1) Max-Planck-Institute for Meteorology, The Ocean in the Earth System, Hamburg, Germany (joachim.segschneider@zmaw.de), (2) University of Hamburg, Institute for Marine Geology, Bundesstr. 55, D-20146 Hamburg, Germany

The impact of volcanic eruptions on the marine carbon cycle is investigated for the example of the Pinatubo eruption with model simulations of the distribution of the ash cloud and deposition on the ocean surface and the impact of the nutrient addition from ash leachates on the oceanic biological production and hence biological carbon pump.

Natural variations of aerosols, especially due to large-magnitude volcanic eruptions, are recognized as a significant climate forcing, altering the Earth's radiation balance and thus tending to cause global temperature changes. While the impact of such events on climate and the terrestrial biosphere is relatively well documented, scientific knowledge of their effects on marine ecosystems and consequent feedbacks to the atmosphere is still very limited. In the deep sea, subaerial eruptive events of global significance are commonly recorded as widespread ash layers, which were often found to be associated with increased abundances of planktic organisms. This has led to the hypothesis that the influx of volcanic ash may provide an external nutrient source for primary production (in particular through iron fertilization) in ocean surface waters. Recent laboratory experiments have demonstrated that pristine volcanic ash indeed releases significant amounts of macronutrients and bioactive trace metals (including phosphate, iron and silica) adsorbed to the surface of the ash particles.
The release of these components most likely has its largest impact in ocean regions where their availability is crucial for the growth of oceanic biomass, which are the high-nutrient but low-productivity (low-iron) areas in the Pacific and the Southern Ocean. These in turn are neighbored by most of those subaerially active volcanoes that are capable of ejecting huge amounts of aerosols into the high-velocity stratospheric wind fields. The dispersal and fallout of ash thus has a high potential to induce globally significant, transient net CO2 removal from the upper ocean and hence the atmosphere. Large-magnitude eruptions such as of Mount Pinatubo in 1991 were in fact followed by a slowing-down in the increase of atmospheric CO2 for several years, entailing a weakening of the global warming trend. For Mount Pinatubo it has been argued that the estimated CO2 uptake (1.6 x 1015 g C) could have been caused by rapid iron fertilization of the Southern Ocean with about 6.3 x 1015 g of ash. However, this would approximate the overall amount of the ash generated by the eruption, of which about 80% fell out over the South China Sea (∼4.9 x 1015 g). This suggests additional avenues for the removal of CO2, among which the 1991 explosive eruption of Cerro Hudson could have played an important role as more than 2 km3 of the aerosols released by the volcano fell out directly over the Southern Ocean.