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Impact of volcanic super-eruptions on the global carbon cycle

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The sensitivity of the climate-biogeochemistry system to extremely large volcanic eruptions (super-eruptions) is investigated using the comprehensive MPI-M Earth System Model (ESM). The model includes an interactive carbon cycle with modules for terrestrial biosphere as well as ocean biogeochemistry.

Here we present and discuss ESM simulations of a very large Northern Hemisphere mid-latitude eruption (Yellowstone) and a very large tropical one (Toba) for different seasons of the eruption. To reduce the influence of internal variability on the experimental outcome, an ensemble of 5 members is analyzed for each of the cases. In the simulated super-eruptions with an assumed atmospheric SO_2 injection of 100 times the 1991 Pinatubo emission, the global annual mean temperature drops by about 3 to 4 K and recovers slowly during the following 15 years. Following a short increase in the first 3 years after the eruption atmospheric CO_2 concentration declines quite rapidly during the next 3 years before reaching a minimum and starting to increase slowly towards the pre-eruption level. This CO_2 dynamics is explained mainly by changes in land carbon storage. Immediately after the eruption, land is a source of carbon to atmosphere primarily due to decrease in plant productivity. Later, reduced heterotrophic respiration in response to surface cooling, which leads to increased carbon storage in soils, mostly in tropical and subtropical regions, prevails over the productivity decrease and the land turns into a carbon sink. Although the climate has completely recovered after 75 years, the carbon cycle has not yet reached equilibrium again. This takes another 75 to 100 years. The ocean acts as a carbon sink in the beginning, primarily due to temperature induced solubility increase, accompanied by changed dynamics in particular in the equatorial Pacific and the marine biology. In the longer term, the ocean compensates for the carbon losses from the atmosphere to the land by increased ocean to atmosphere fluxes, resulting in a net loss for the ocean.