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Modelling the climate-carbon cycle response to stratospheric volcanic aerosol radiative forcing

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Large volcanic eruptions can have a significant influence on climate, and can indirectly influence the global carbon cycle through climate-carbon cycle feedbacks. As such, major volcanic eruptions offer an opportunity to improve our understanding of both climate responses to radiative forcing and global carbon cycle responses to climate. However, the magnitudes of both the climate and carbon cycle responses to volcanic forcings are difficult to quantify due to the internal variability of the climate system on interannual timescales, and the low temporal resolution of ice core CO_2 records. Nevertheless, the tremendous opportunity offered by studying such perturbations and the relevance of the response for future coupled climate-carbon behaviour motivates us to investigate such events using coupled climate-carbon Earth system models (ESMs). In this study, three ESMs (SIMEARTH, CLIMBER VECODE, and CLIMBER LPJ) are used to simulate the effects of different magnitudes of volcanic eruption on the coupled global climate-carbon cycle system. Simulated volcanic events range in magnitude from Volcanic Explosivity Index (VEI) 4 (e.g. Mount Pelee, 1902) to 8 (e.g. the 1258 ice core event), and include the VEI 6 Mount Pinatubo eruption in 1991. All models simulate similar levels of cooling in response to a volcanic event of a given magnitude, but the atmospheric CO_2 response is more variable. For example, a VEI 6 eruption results in a modelled temperature decrease of 0.3^oC to 0.4^oC and atmospheric CO_2 decrease of 0.1ppm to 3ppm. Key differences in parameterizations, such as how soil respiration and net primary productivity respond to temperature and atmospheric CO_2, have major impacts on the modelled dynamics of atmospheric, land, and ocean carbon. The usefulness of characterising the simulated response of the global carbon cycle to this type of perturbation with metrics used in previous projects (e.g. C4MIP), such as the sensitivity of the global carbon cycle to volcanic aerosol-induced cooling (γ) (Friedlingstein et al., 2006), and the total land carbon response to CO_2 (β) (Frank et al., 2010), is also investigated.

Frank, D.C. et al. (2010), Ensemble reconstruction constraints on the global carbon cycle sensitivity to climate, Nature, 463(7280), 527–530, doi:10.1038/nature08769.

Friedlingstein, P. et al. (2006), Climate–Carbon Cycle Feedback Analysis: Results from the C4MIP Model Intercomparison, Journal of Climate, 19(14), 3337–3353, doi:10.1175/JCLI3800.1.