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Ocean Response to Volcanic Eruptions in CMIP5 Coupled Simulations

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Questions regarding the ocean response to changes in atmospheric aerosol loading have arisen in several contexts recent years. Here we exploit the availability of new simulations produced as part of CMIP5 to revisit the ocean response to the five largest tropical volcanoes of the last 135 years (Krakatau, Santa Maria, Agung, El Chichón, and Pinatubo) in a set of 36 historical climate simulations produced using eight widely used climate models. All models show an annual average reduction in net surface solar radiation of 1-5 W m^{-2}, a drop in net surface heat flux of 1-3 W m^{-2}, and a resulting decline in SST of 0.1-0.3 K. Sea ice extent and mass also increase by about 5%. For smaller eruptions SST may recover in a few years, but our results confirm the suggestion of previous studies that the impacts on ocean heat content of major eruptions may persist for decades. The increase in sea ice area and mass also persists well beyond the lifetime of stratospheric aerosols due to the reinforcing impact of solar albedo feedback and reductions in thermodynamic surface heat loss. The cool SST signal also penetrates into the subsurface ocean, lowering 0-1000m temperature by an average of roughly 0.03 K, and persisting for many decades, masking some of the anthropogenic warming signal. Indeed, comparisons of simulations with and without volcanic aerosols show that the concentration of eruptions in the early years of the 20th century and again in the near the end of the century may mask some of the acceleration of ocean heating that might otherwise have been observed.

A number of previous studies have explored the connection between volcanic eruptions and interannual to decadal climate variability with contradictory results. Here we combine the use of extensive numbers of ensemble members with a Rotated Extended Empirical Orthogonal Function analysis to further discriminate the natural and forced response, the result of which is no compelling evidence of a link between the timing of an eruption and a shift in phase of ENSO.

Finally we examine the impact of eruptions on the overturning circulation, most particularly the overturning in the North Atlantic and confirm previous results suggesting that volcanic eruptions may enhance the overturning circulation (and consequently increase northward heat transport) due to increases in ocean surface density in the northern Atlantic sector. A comparison shows that the models vary by at least a factor of four in their sensitivity, the most sensitive models being those which have the most Atlantic meridional overturning variability in general.