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Climatic Impact of Tropical Volcanic Eruption: the Role of Background Climate and Volcanic Perturbation

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The 1815 CE Tambora eruption led to the "Year Without a Summer" and caused serious crop failure and famines across Europe and North America. However, its influence in China was complex and differ among the proxy and documentary evidences, raising the question about the relative role of the background climate and volcanic perturbation. Here we use the Community Earth System Model (CESM) to simulate the climate responses of four forcing scenarios, i.e. the single Tambora-size volcanic perturbation, plus scenarios with the cold background climate setup by the coincident Dalton Minimum, the preceding 1809 CE unknown eruption, and the one under projected global warming.

Our results show significant cooling as a result of the reduction in surface solar flux and the increase in cloud cover. Rainfall reduction is significant over tropical and most monsoon regions as a consequence of weakened monsoon circulation and vertical lifting. Both responses remain relatively stable at global level as we add layers of different background condition. In Asia, the cooling and rainfall reduction is about twice and ten times the global averages. However, the sensitivity of precipitation w.r.t temperature reduction decreases about 20% under the cold background with the preceding Dalton Minimum and 1809 CE unknown eruption. Reduction in convective precipitation dominates the precipitation response in monsoon Asia, and the effect decreases as we introduce the cold background. Projecting the same Tambora size eruption into RCP4.5-based warming, we find larger cooling response suggesting higher temperature sensitivity. However, precipitation reduction is 35% less, suggesting a significant reduction of precipitation sensitivity when comparing to the volcanic-only scenario. The role of background climate in regulating volcanic forced climate response and the difference among the cold vs. warm climate have important implications for evaluating the climate aftermath of future eruptions and stratospheric climate engineering proposals.