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Climate extreme responses to volcanic eruption assessed from CMIP5 multi-models

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This study analyzes extreme temperature and precipitation responses over the global land to five explosive tropical volcanic eruptions (Krakatau, Santa Maria, Agung, El Chichon and Pinatubo) that occurred since 1880s using CMIP5 multi-model simulations. In case of low latitude eruptions, aerosols tend to spread out globally and appropriate to investigate the global climate responses. We used historicalNat (NAT) simulations which were integrated under natural (solar and volcanic) forcing only (13 models). We also use historical (ALL) simulations integrated under both anthropogenic and natural external forcing (17 models). First, changes in annual warmest day (TXx) and coldest night (TNn) temperature indices during post-eruption years are examined by compositing responses to the five volcanic eruptions. Extreme temperature decreases occurred in most global land areas during post-eruption years, with good agreement between models are stronger than the internal variability ranges (estimated from bootstrap random sampling), representing robust responses. Further, the cooling responses are greater in NAT than ALL experiment, due to absence of anthropogenic warming. There is a close relationship between annual extreme and mean temperature responses to volcanic forcing, indicating similar mechanisms operating (inter-model correlation r = 0.91 for TXx, r = 0.86 for TNn). In addition, surface air temperature and surface specific humidity responses are significantly correlated across models (r = 0.83), consistent with the Clausius-Clapeyron relation. Second, we analyzed extreme precipitation responses to volcanic forcing using annual extreme consecutive 5-day precipitation (Rx5day), annual total precipitation on very wet days (R95p), and daily precipitation amount on rainy day (SDII). Extreme and mean precipitation reductions are identified especially in Northern and Southern Hemispheric summer monsoon regions, with good inter-model agreement in sign of the responses. The precipitation decreases are also larger than the internal variability ranges during two post-eruption years. Unlike temperature responses, NAT does not have larger response than ALL, implying weak influence of anthropogenic forcing on monsoon precipitations. The extreme precipitation changes are found to be closely related to mean precipitation response over the monsoon regions (r = 0.63 to 0.76). In terms of mechanisms, analysis based on a moisture budget equation reveals that the precipitation decrease over the monsoon region is explained by evaporation decrease, dynamic, and thermodynamic contributions. Particularly, the dynamic contribution is found to have large influence on inter-model spread in precipitation responses with high inter-model correlation with mean and extreme precipitation changes (r = 0.52 to 0.91). Our results suggest that temperature and precipitation extremes significantly respond to volcanic eruptions, which largely resemble mean climate responses.