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Impact of volcanic eruptions on temperature and precipitation extremes: CMIP5 multi-model analysis

Seungmok Paik and Seung-Ki Min

Pohang university of science and technology, Pohang, Korea (bekmook@postech.ac.kr)

This study analyzes extreme temperature and precipitation responses over the global land to five explosive low-latitude volcanic eruptions (Krakatau, Santa María, Agung, El Chichón and Pinatubo) that occurred since 1880s using CMIP5 multi-model simulations integrated under natural (solar and volcanic) forcing only (13 models). First, changes in annual warmest day (TXx) and coldest night (TNn) temperature indices during post-eruption years are examined. Extreme temperature decreases are observed over a large part of the global land with good inter-model agreement. Amplitude is well beyond the estimated ranges of internal variability (estimated from bootstrap sampling), representing robust cooling responses. There is a close relationship between annual extreme and mean temperature responses, indicating similar mechanisms operating (inter-model correlation r = 0.91 for TXx, r = 0.86 for TNn). In addition, decrease in surface specific humidity after eruptions is closely related to cooling across models (r = 0.83), which indicates the Clausius-Clapeyron relation. Next, extreme precipitation responses to volcanic forcing are analyzed 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 with good inter-model agreement are identified especially in Northern and Southern Hemispheric summer monsoon regions. The precipitation decreases are also larger than the internal variability ranges during two post-eruption years with a significant mean-extreme relation over the monsoon regions (r = 0.63 to 0.76). In terms of mechanisms, a moisture budget analysis reveals that the precipitation decrease over the monsoon region is explained by evaporation decrease, dynamic, and thermodynamic contributions. The precipitation responses to volcanic forcing are very different among model simulations and it is found that the dynamic contribution has larger influence on inter-model spread in mean and extreme precipitation changes. These model-based results are largely supported by an observational analysis based on the HadEX2 data set for the recent three volcanic eruptions, although some limitations exist due to spatio-temporally sparse observations. Our results suggest that temperature and precipitation extremes significantly respond to volcanic eruptions, which largely resemble mean climate responses.