Divergent hydrological responses to volcanic eruptions in CMIP5 multi-models

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Explosive low-latitude volcanic eruptions emit sulfur dioxide gas to the stratosphere, which is oxidized to sulfate aerosols. The aerosols scatter incoming solar radiation, reducing energy inflow at the surface and induces global temperature cooling and precipitation decrease, during a few years. Climate models can simulate overall responses of cooling but there remains a large inter-model spread for the precipitation responses to tropical volcanic eruptions. A recent study (Paik and Min 2018) found that the large inter-model uncertainty in precipitation response is associated with different responses in atmospheric circulation changes among models. This study investigates causes of the inter-model uncertainty in the dynamic responses to volcanic forcing focusing on El Niño occurrence after eruptions. It is found that El Niño affects monsoon regional precipitation through altering atmospheric circulation changes, especially over the South Asia and north part of South America in boreal summer and South America and Australia in austral summer. Most of the CMIP5 models simulate El Niño occurrence after eruptions but with a large difference in its amplitude. When removing El Niño influences from each model, precipitation responses decrease with reduced inter-model difference, representing that the diverse El Niño response among models is partly responsible for the inter-model uncertainty in precipitation (dynamic circulation) responses. We also find that the initial Africa cooling and drying responses are associated with El Niño occurrence and intensity. As Khodri et al. (2017) suggested, the precipitation reduction over Africa induces Kelvin waves which propagate eastward ahead to the western Pacific, which affects El Niño initiation through altering Walker circulation. In addition, large inter-model uncertainties are in part due to different strength of the volcanic forcing implemented among models. Different volcanic forcing based on Sato et al. (1993) and Ammann et al. (2003, 2007) exhibits a systematic difference in the surface downward shortwave radiation, which causes significant differences in Africa cooling and drying responses and El Niño responses to volcanic eruptions. Further, model's ENSO intensity is also found to contribute to the diverse El Niño responses among the models simulated with identical volcanic forcing. In conclusion, we show that inter-model spread in monsoon regional precipitation to volcanic eruptions arises mainly from the diverse El Niño responses among models, which is partly due to different volcanic forcings implemented as well as different ENSO characteristics among models.

Key words: Volcanic eruptions, CMIP5 models, Precipitation, El Niño, Uncertainty

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