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The Hydrological Effects of Volcanic Aerosols in Asian Monsoon Region

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Proxy-model comparisons show mismatches on hydrological effects of volcanic aerosols in Asian monsoon region. This was often imputed to large uncertainty of models, which hampers the exploration with model simulations on understanding the mechanism of these hydrological effects. In this study, we show the plausibility of multi-model ensemble mean (MME) to reproduce these hydrological effects in Asia summer monsoon related regions, and investigate their potential mechanisms with model outputs. We use MME of 8 climate models from last millennium experiment of Coupled Model Intercomparison Project 5 in 1300-1850 AD. After transferring temperature and precipitation data into drought indices Palmer Drought Severity Index (PDSI) and 12-month of Standardized Precipitation Index (SPI12), we compared them with tree ring-based proxy data Monsoon Asia Drought Atlas (MADA). Temporal superposed epoch analysis (SEA) on MADA, MME of PDSI and SPI12 with Monte Carlo model significance tests show significant reduction of MADA in 1 year after the volcanic aerosol injection (year 1) to year 3, similar but quicker response are shown in MME of PDSI and SPI12 with significant reduction in the volcanic aerosol injection year (year 0) to year 2. MME of East Asian (EA) and South Asian summer monsoon (SASM) indices decreased significantly in year 0 to year 2 quantify the weakening of EASM and SASM from the decreased land-sea thermal contrast. Spatial SEA on MME of PDSI and SPI12 show significant drying trend in Asia monsoon related regions from year 0 to year 2, the patterns stay the same even after removing the impact of El Niño-Southern Oscillation. Seeing through the time course of the spatial pattern, they show convergence with analysis on MADA except for areas that are lack of original tree ring data. The average difference spatial pattern between average of four years after the volcanic aerosol injection (from year 0 to year 3) and before them (from year -4 to year -1) of MME of PDSI agrees with patterns in previous studies using proxy data as well as observation. These analyses show the plausibility of models on reproducing the hydrological effects of volcanic aerosols in Asian summer monsoon regions. Furth correlation regression analysis, between MME of precipitation/temperature and radiation, heat flux, humidity and evaporation, show significant correlation between temperature and longwave radiation, while precipitation is highly correlated with latent heat flux, humidity and evaporation. Comparison on average difference spatial pattern of these variables identifies different response mechanism between representative drought and wet areas. This comes from different variation of longwave radiation, and further lead to different response of sensible and latent heat flux, humidity and evaporation, which result in opposite drought and wet conditions. These findings identify the availability of MME and spatial-temporal analysis to better study the hydrological impacts of volcanic aerosols, and contribute to better understanding the mechanism of stratospheric aerosols' hydrological effects in Asian summer monsoon regions.