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Combined effects of anthropogenic aerosols and global warming on the South Asian Monsoon

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The South Asian monsoon (SAM) precipitation has been generally regarded to exhibit contrasting responses to greenhouse gas (GHG) and anthropogenic aerosol forcing, although it is not adequately clear as to how it might respond to the combined influence of GHG and aerosol forcing. The present study examines the individual and combined effects of global warming and anthropogenic aerosols on the SAM based on a suite of numerical experiments conducted using the IITM Earth System Model version2 (IITM-ESMv2). Four sets of 50-year model integrations are performed using IITM-ESMv2 with different anthropogenic forcings 1) Pre-Industrial control, 2) anthropogenic aerosols of 2005 3) CO_2 concentrations of 2005 4) anthropogenic aerosols and CO_2 of 2005. In the experiment with the elevated CO_2 level of 2005, an intensification of SAM precipitation and strengthening of large-scale monsoon cross-equatorial flow is noted relative to the PI-CTL run. In contrast, the experiment with elevated anthropogenic aerosols of 2005 shows a decrease of SAM precipitation and weakening of monsoon circulation relative to the PI-CTL run. A striking result emerging from this study is the strong suppression of SAM precipitation, pronounced weakening of the monsoon circulation and suppression of organized convection in response to the combined radiative effects of elevated CO_2 and anthropogenic aerosols relative to the PI-CTL run. By diagnosing the model simulations it is noted that the radiative effects in the combined forcing experiment lead to a pronounced summer-time cooling of the NH as compared to the equatorial and southern oceans which are predominantly influenced by global warming, thereby creating a north-south differential radiative forcing over the Indian longitudes. Additionally, the influence of absorbing aerosols over South and East Asia creates a surface radiation deficit over the region, stabilizes the lower troposphere, slows down the monsoon winds and reduces surface evaporation. Although the anticyclones over the subtropical Indian Ocean intensify in the combined forcing experiment, the model simulation shows that much of the precipitation enhancement occurs to the south of the equator over the Indian Ocean whereas the moisture transport and convergence to the north of the equator is substantially reduced. Furthermore, the combined forcing experiment shows that anomalous large-scale descent over the subcontinent reinforces the suppression of organized convection giving rise to more intense breaks and weaker active spells in the southwest monsoon on sub-seasonal time-scales. This study hints that future decreases in NH aerosol emissions could potentially reverse the ongoing decreasing trend of the observed SAM precipitation since 1950s in a purely global warming environment.