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Quantifying the contributions of anthropogenic and natural forcings to climate changes over global land during 1946–2005

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In this study, the contributions from changes in man-made greenhouse gases (GHG), anthropogenic aerosols (AA), and land use (LU), as well as natural solar and volcanic
(NAT) forcing changes, to observed changes in surface air temperature (T) and precipitation (P) over global land, especially over arid-semiarid areas, during 1946–2005 are quantified using observations and climate model simulations from the Coupled Model Intercomparison Project Phase 5 (CMIP5). Results show that the anthropogenic (ANT) forcings dominate the ubiquitous surface warming seen in observations and lead to slight increases in precipitation over most land areas, while the NAT forcing leads to small cooling over land. GHG increases are the primary factor responsible for the anthropogenic climate change, while the AA forcing offsets a large part of the GHG-induced warming and P changes. The LU forcing generally contributes little to the T and P changes from 1946 to 2005 over most land areas. Unlike the consistent temperature changes among most model simulations, precipitation changes display a large spread among the models and are incomparable with the observations in spatial distributions and magnitude, mainly due to its large internal variability that varies among individual model runs. Using an optimal fingerprinting method, we find that the observed warming over land during 1946–2005 can be largely attributed to the ANT forcings, and the combination of the ANT and NAT forcings can explain about 85$\sim$95% of the observed warming trend over global land as well as over most arid-semiarid regions such as Northern China. However, the anthropogenic influences on precipitation over the past 60 years are generally undetectable over most land areas, including most arid-semiarid regions. This indicates that internal variability is still larger than the forced change for land precipitation.