Global and Regional Climate Responses to Black Carbon Emissions from the Arctic and Mid-latitudes

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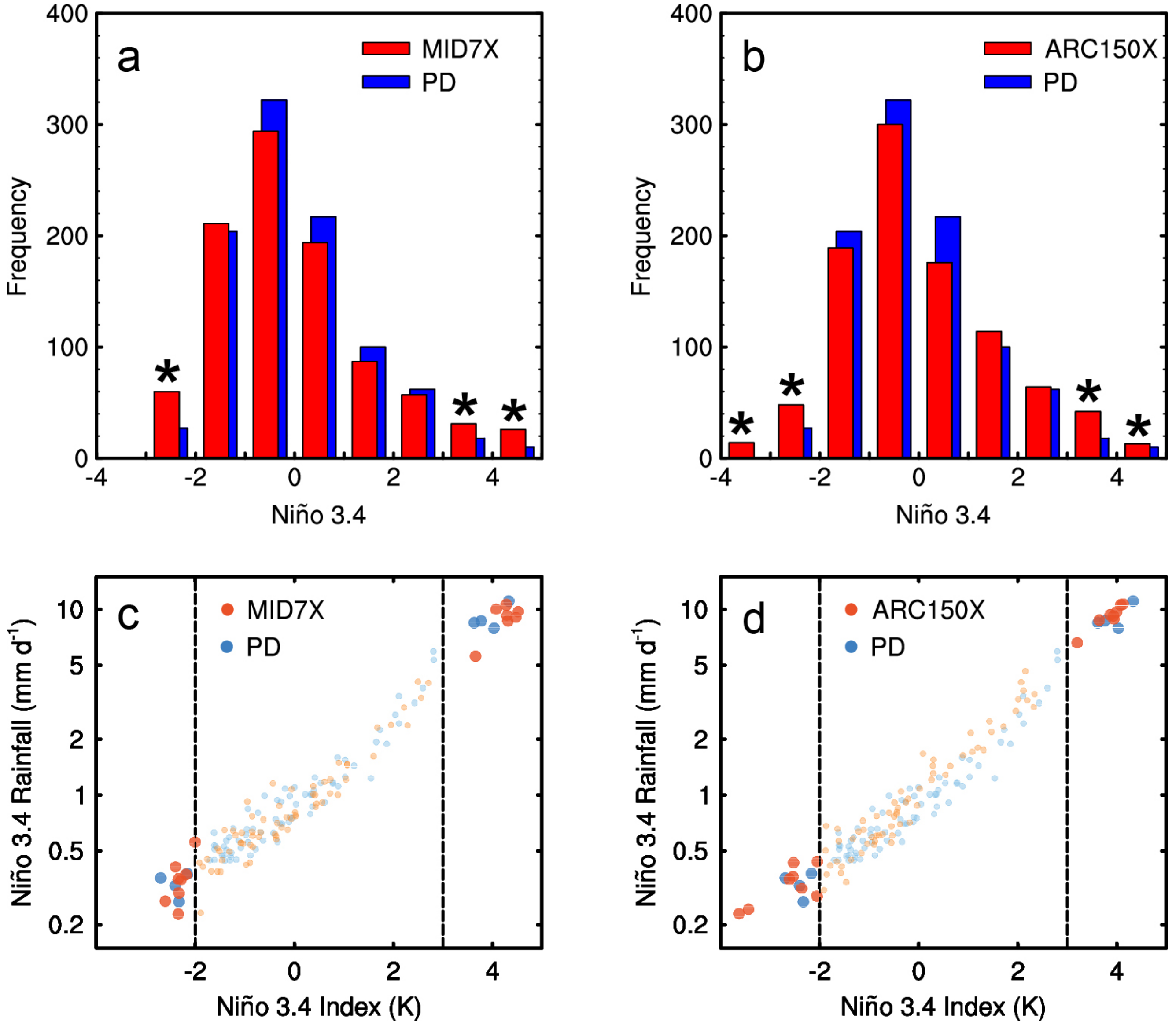
Black carbon (BC) particles exert a potentially large warming influence on the Earth system, which drew attentions for climate mitigation from reducing BC emissions. For the first time, we evaluate climate responses, non-linearity, and short-term transient responses to BC emission perturbations in the Arctic, mid-latitudes, and globally based on a comprehensive set of emission-driven experiments using the Community Earth System Model (CESM). We found that the BC effects do not scale linearly with the amount of emissions. While stronger BC emission perturbations have a higher burden efficiency (defined as the ratio of burden to emission), their temperature sensitivity is lower. Our CESM results show that BC can impact air temperature much faster than greenhouse gases, with transient temperature responses in the Arctic and mid-latitudes approaching a quasi-equilibrium state at a timescale of 2–3 years in the coupled system. We also found that BC originating from mid-latitude continental sources changes cloud structure over downwind oceans and reduces land-sea thermal contrast and, consequently, weakens the East Asian winter monsoon winds. A strong increase in the Arctic BC also weakens East Asian winter monsoon through changing large-scale circulations. In addition, the increases in both Arctic and mid-latitude BC emissions are found to weaken latitudinal temperature gradient and poleward heat transport, lead to tropical energy convergence, increase surface temperature of the tropical oceans, and consequently increase the frequency of extreme El Nino-Southern Oscillation events.

Keywords: Black Carbon, Climate Response


a
MID7X
PD
Frequency
Niño 3.4
b
ARC150X
PD
Frequency
Niño 3.4
c
MID7X
PD
Niño 3.4 Rainfall (mm d-1)
Niño 3.4 Index (K)
d
ARC150X
PD
Niño 3.4 Rainfall (mm d-1)
Niño 3.4 Index (K)