Disentangling the impacts of anthropogenic aerosols on terrestrial carbon cycle during 1850-2014

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Aerosols have a dimming and cooling effect and change hydrological regimes, thus affecting carbon fluxes, which are sensitive to climate. Aerosols also scatter sunlight, which increases the fraction of diffuse radiation, increasing photosynthesis. Although previous studies have quantified the impacts of some of these factors separately, there remains no clear conclusion whether the physical impacts of aerosols on land carbon fluxes is larger through diffuse radiation change than through changes in other climate variables. In this study, we quantified the overall physical impacts of anthropogenic aerosols on land C fluxes and explored the contribution from each factor using a set of factorial simulations driven by climate and aerosol data from the IPSL-CM6A-LR experiments from 1850 to 2014. A newly-developed land surface model which distinguishes diffuse and direct radiation in canopy radiation transmission, ORCHIDEE\textsubscript{DF}, was used. Specifically, a sub-grid scheme was developed to distinguish the cloudy and clear sky conditions. We found that anthropogenic aerosol emissions since 1850 cumulatively enhanced the land C sink by 22.6 PgC. 78\% of this C sink enhancement is contributed by aerosol-induced increase in the diffuse radiation fraction, which is much larger than the effect of the aerosol-induced dimming. The cooling of anthropogenic aerosols increases the C sink in low latitudes but decreases the C sink in high latitudes and overall slightly increases the global land C sink. Compared with radiation and temperature changes, aerosol-induced precipitation changes have limited impacts. The dominant role of diffuse radiation changes in affecting historical land C fluxes found in this study implies that future aerosol emissions may have a much stronger impacts on the C cycle through changing radiation quality than through changing climate alone. Earth system models need to take into account the diffuse radiation fertilization effect, in order to better evaluate the impacts of climate change mitigation scenarios.