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Factors Affecting Aerosol Radiative Forcing

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Rapid industrial and economic growth has meant a large amount of aerosols in the atmosphere with strong radiative forcing (RF) upon the climate system. Over parts of the globe, the negative forcing of aerosols has overcompensated for the positive forcing of greenhouse gases. Aerosol RF is determined by emissions and various chemical-transport-radiative processes in the atmosphere, a multi-factor problem whose individual contributors have not been well quantified.
In this study, we analyze the major factors affecting RF of secondary inorganic aerosols (SIOAs, including sulfate, nitrate and ammonium), primary organic aerosol (POA), and black carbon (BC). We analyze the RF of aerosols produced by 11 major regions across the globe, including but not limited to East Asia, Southeast Asia, South Asia, North America, and Western Europe. Factors analyzed include population size, per capita gross domestic production (GDP), emission intensity (i.e. emissions per unit GDP), chemical efficiency (i.e. mass per unit emissions) and radiative efficiency (i.e. RF per unit mass).
We find that among the 11 regions, East Asia produces the largest emissions and aerosol RF, due to relatively high emission intensity and a tremendous population size. South Asia produce the second largest RF of SIOA and BC and the highest RF of POA, in part due to its highest chemical efficiency among all regions. Although Southeast Asia also has large emissions, its aerosol RF is alleviated by its lowest chemical efficiency. The chemical efficiency and radiative efficiency of BC produced by the Middle East–North Africa are the highest across the regions, whereas its RF is lowered by a small per capita GDP. Both North America and Western Europe have low emission intensity, compensating for the effects on RF of large population sizes and per capita GDP.
There has been a momentum to transfer industries to Southeast Asia and South Asia, and such transition is expected to continue in the coming years. The resulting relocation of emissions would meant drastic changes in both the spatial distribution and the magnitude of RF, with consequences on regional and global climate forcing. Our findings are relevant to global aerosol control and climate mitigation.