Impact of Aerosols on Climate Changes in the 20th Century

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Climate impact by anthropogenic drivers gives high concerns in climate change simulation. Intergovernmental Panel on Climate Change AR4 emphasized the role of aerosol on climate, besides the greenhouse gases (GHGs), due to its negative significant radiative forcing. This study is interested in anthropogenic aerosol effects on long-term climate through direct and indirect radiative process and uses HadGEM2-AO developed by the United Kingdom Met office.

Unlike the long-lived GHGs, which are distributed uniformly over the globe, aerosol effects with the short lifetime appear more regional and less persistent than those of GHGs. In Figure 1, aerosol optical depth in Northern high latitudes has been dramatically increasing since the 1950s in East-Asia, North America and Europe. There are significant changes in Earth`s radiative balance indirectly through their effect on cloud properties such as cloud albedo, droplet size, number concentration, brightness, and amount. Especially, cloud amount response by aerosol, the increases in low level cloud, is shown in enhancing shortwave reflection. We found that radiative flux perturbation at the top of atmosphere is estimated to be –0.44 Wm^{-2}, globally in the middle of the 20th Century. This forcing is comparable in magnitude to GHGs forcing 0.43 Wm^{-2} but opposite in sign.

Reductions in the amount of solar irradiance lead to changes in the atmospheric temperature. In Figure 2, global temperature anomaly (HIST experiment, including all forcing) during the middle of the 20th Century remains cool and steady at approximately the same level in pre-industrial. Particularly, the largest temperature reduction is found in the Northern Hemisphere because of a larger aerosol burden there. As a result of this unbalanced cooling, the Intertropical Convergence Zone is displaced southward by a few hundred kilometers. After the late 1970s, GHGs forcing became the dominant factor, which significantly contribute to global warming.

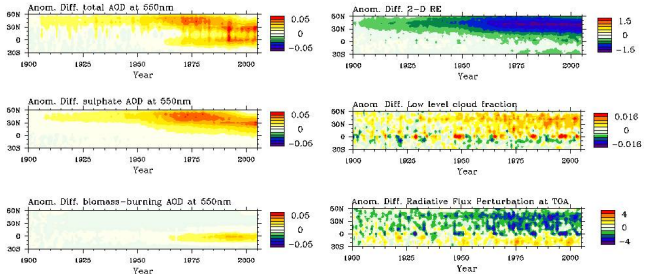

Figure 1. Latitude-time sections of zonal mean anomalies (total Aerosol Optical Depth, cloud effective radius, low level cloud fraction, net radiative flux perturbation) from 1900 to 2005.

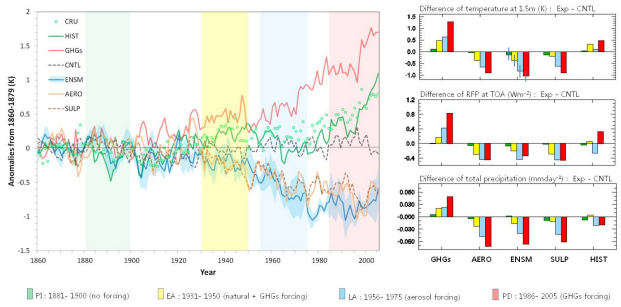

Figure 2. Global annual mean surface air temperature anomalies, for Climate Research Unit data (green open circle), all forcing historical experiment (green line), GHGs only (red line), no forcing control experiment (dotted black line), aerosol ensemble mean experiment (blue line), aerosol only experiment (brown line), and sulphate only experiment (dotted brown line) from the HadGEM2-AO climate model.