Global Change in the Contexts of Atmospheric Chemistry and Air Pollution

Kengo Sudo[1,2]

[1] Graduate School of Environmental Studies, Nagoya University, Japan

[2] Frontier Research Center for Global Change, JAMSTEC, Japan

kengo@nagoya-u.jp

Atmospheric ozone (O_3) and aerosol species can cause significant impacts on climate and atmospheric environment. Global changes in ozone like stratospheric O_3 depletion and tropospheric O_3 increase since the last century, mainly caused by air pollution, have been playing a significant role in climate change. Aerosols like BC/OC and other reflective (hygroscopic) components are likely to be well related to the past/future climate change as well. These air pollution related processes and climate change are considered to occur interactively as recognized as an issue "atmospheric chemistry / climate interaction (AC&C)".

For examining the impacts of global ozone changes on climate, we first study the climate response to changes in global tropospheric and stratospheric ozone (O_3) distributions from preindustrial times (PI) to the present day (PD) through a set of model simulations. We performed distinct scenario experiments to isolate the impacts of (1) increases in long-lived GHGs (LLGHGs), (2) emission-induced increase in tropospheric ozone (TOZ), and (3) halogen-induced decrease in stratospheric ozone (SOZ). In the simulation, tropospheric O_3 burden increases by ~10 DU (0.49 W m-2 radiative forcing) up to the present due to the emission increases (TOZ), but decreases by ~1 DU due to the halogen-induced O_3 depletion (SOZ). As an equilibrium response, the emission-induced O_3 increase (TOZ) causes a global and annual mean surface temperature increase of 0.29 degree Celsius (NH: 0.31, SH: 0.27 degree Celsius), equivalent to 13% of the estimated LLGHGs impact (2.29 degree Celsius). Responding to TOZ, particularly large warming occurs in North America, Middle East, and Asia, apparently reflecting the spatial distributions of the radiative forcing from TOZ. Our sensitivity simulation with evenly distributed TOZ increase suggested that such inhomogeneous warming response largely reflects the horizontal pattern of the tropospheric O_3 increases as well as inherent sensitivity of the climate model. The SOZ decrease, causing decreases in long-wave heating and O_3 input to the troposphere, leads to a surface cooling of -0.06 degree Celsius. Both TOZ and SOZ cause cooling in the lower to middle stratosphere (0.5-1.0 degree Celsius). LLGHGs also cool the middle to upper stratosphere, but warm the lower stratosphere in the extratropics due to adiabatic heating associated with the enhanced Brewer-Dobson circulation.

Our future simulations (projection) show that both climate change (warming) and stratospheric O_3 change (recovery), expected during the 21st century, have large impacts on tropospheric O_3 chemistry including time evolution of methane for any emission scenarios (SRES B1, A1, and A2). The model inter-comparison for the IPCC-AR4 shows significant impacts of future climate change on surface O_3 in the participating models, but highlights a large diversity in the model results as well.