Application of online-coupled WRF-CMAQ to annual ozone simulation over East Asia

○Sha Yi[1)], Hikari Shimadera[1)], Akira Kondo[1)]
[1)] Osaka University

【Background】The presence of aerosol particles affects the solar radiation by scattering and absorption in the atmosphere, which is called the aerosol direct effect. The direct effect can cause changes in photolysis rates for photochemistry, surface temperature that affects thermally-driven reactions, and atmosphere stability that affect vertical dispersion of air pollutants. In East Asia with substantial aerosol loading, the direct effect has a large impact on $PM_{2.5}$ simulation[1)]. In this study, the online coupled WRF-CMAQ modeling system was applied to annual ozone simulation over East Asia in order to evaluate the performance of the online model and the impact of the aerosol direct effect on the atmospheric chemical transport of ozone.

【Methodology】The online coupled CMAQ v5.0.2 with WRFv3.4 was applied to East Asia for a year from January to December 2014. The model domains in WRF and CMAQ were respectively discretized into 140x120 and 130x110 horizontal grid cells (45-km resolution) with 30 vertical layers (between the surface and 100 hPa). The simulations were conducted for the following two cases: one-way case without the aerosol direct effect and two-way case with the aerosol direct effect. By comparing the two simulation results, we analyzed the impact of changes in meteorological fields caused by the aerosol effect on the formation and transport of ozone in East Asia.

【Results】Fig. 1 shows the time series of the observed and simulated daily maximum 8-h O_3, daily mean NO_2 and $PM_{2.5}$ concentrations and the corresponding contribution of the aerosol direct effect (two-way – one-way) in Beijing, 2014. The aerosol direct effect has a positive effect on $PM_{2.5}$ and NO_2 concentration and a negative effect on O_3 concentration in Beijing. The direct effect can decrease the surface shortwave radiation, which results in lower surface temperature and PBL height. These changes further exacerbate the accumulation of ground-level air pollutants. O_3 concentration in Beijing decreased due to titration with NO accumulated in more stable PBL and decrease in photolysis rates caused by increased $PM_{2.5}$. Fig. 2 shows the spatial distributions of the simulated O_3 concentration and the corresponding contribution of the aerosol direct effect on February 26, which is characterized by the highest $PM_{2.5}$ concentration in Beijing within the simulation period and remarkable long-range transport from the Asian Continent to Japan. The negative contribution of the aerosol direct effect was distributed from the polluted upwind area to the downwind area.

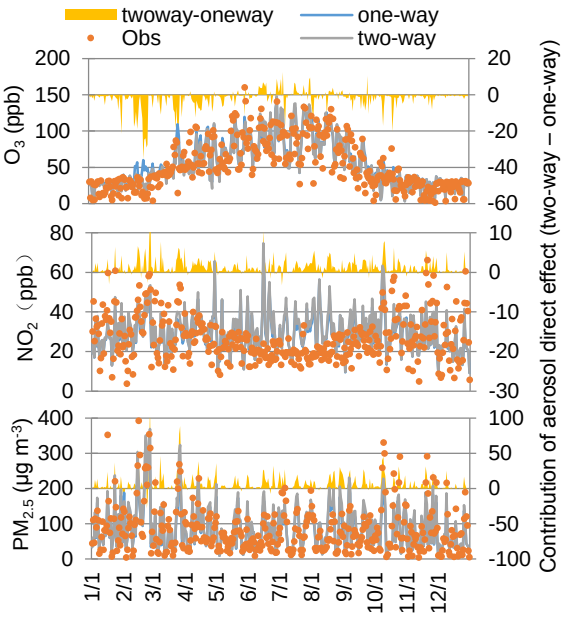

Fig. 1 Time series of observed and simulated O_3, NO_2 and $PM_{2.5}$ concentrations in Beijing, 2014.

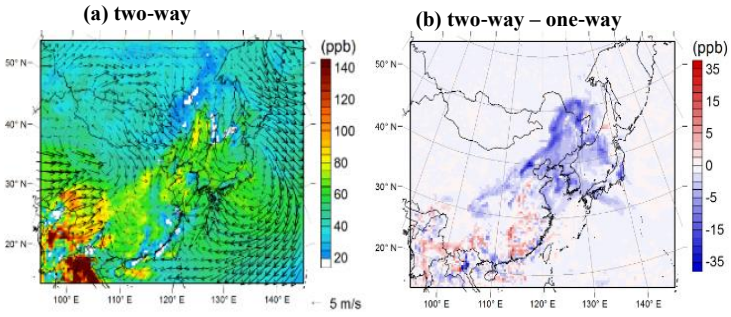

Fig. 2 Spatial distributions of simulated O_3 concentration and the corresponding contribution of the aerosol direct effect at 17:00 JST on February 26, 2014.

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1) Sekiguchi A., Shimadera H., Kondo A. (2016) Evaluation of the impact of aerosol direct effect on annual $PM_{2.5}$ simulation over East Asia, 57th meeting of the Japan Society for Atmospheric Environment.