Investigating aerosol direct effects on $PM_{2.5}$ and O_3 air quality in Continental Southeast Asia by using an online coupled WRF-CMAQ model

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【Introduction】Assessment of aerosol direct effects on air quality can support for better development of pollution control strategies since the effects can cause increase or decrease in air pollutant concentrations through change in meteorological conditions. In this study, an online coupled modeling system composed of Weather Research and Forecasting (WRF) model and Community Multiscale Air Quality (CMAQ) model was applied to investigate the aerosol direct effects on meteorology and air quality with the focus on particulate matter with an aerodynamic diameter of 2.5 μm or less ($PM_{2.5}$) and ozone (O_3) in Continental Southeast Asia where has suffered significant air pollution recently due to rapid development. This topic has attracted great attention as aerosol direct effects on air quality is far from being well understood in the region.

【Methodology】The WRF-CMAQ modeling system was coupled in both one-way and two-way online for entire historical year 2014 at a horizontal resolution of 24 x 24 km. The contributions of aerosol direct effects on meteorology and air quality were calculated as the difference between the results of two-way online simulation and one-way online simulation since the feedback from chemistry to meteorology in the two-way online coupled model is equivalent to the aerosol direct effects. Model performance was also evaluated for both meteorology and air quality applications in order to assess the ability of the modeling system in reproducing the observations.

【Results】In four focused countries including Cambodia, Laos, Thailand and Vietnam, the aerosol direct effects were clearly recognizable. The direct effects moderately decreased shortwave radiation, temperature, planetary boundary layer (PBL) height, and wind speed by -6.17%, -0.24°C, -7.21%, and -1.64%, respectively. These percentages were -9.61%, -0.44°C, -10.61%, and -2.55% in dry season, and -2.34%, -0.04°C, -2.05%, and -0.62% in wet season, respectively. Consequently, the response of meteorology to direct effects lead to the change in ground-level $PM_{2.5}$ and O_3 concentrations. $PM_{2.5}$ concentration was found to increase by +6.00% and O_3 concentration was found to decrease by -1.55% for the whole year (Figure 1). For each season, $PM_{2.5}$ concentration was increased by +7.12% in dry season and +0.99% in wet season. O_3 concentration was decreased by -2.82% in dry season while slightly increased by +0.56% in wet season. The magnitude of direct effects was large at high $PM_{2.5}$ polluted periods and locations. Correlation matrix indicated that the increasing effect of aerosol on $PM_{2.5}$ concentration was caused by the decrease in above mentioned meteorological variables. The increase or decrease in O_3 concentration depended on the responses of atmospheric dynamics as well as photolysis rates of photochemical reactions to direct effects.

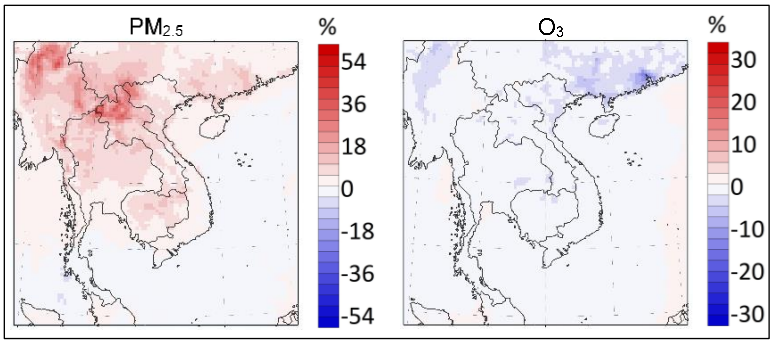

Figure 1. Spatial distribution of contribution percentages of aerosol direct effects to $PM_{2.5}$ and O_3 concentrations for the whole year