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Numerical assessment of $PM_{2.5}$ and O_3 air quality in continental Southeast Asia: Baseline simulation and aerosol direct effects investigation

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ABSTRACT

An online coupled modeling system composed of Weather Research and Forecasting (WRF) model and Community Multiscale Air Quality (CMAQ) model was applied to assess 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. Comprehensive model evaluations demonstrated that the modeling system had the capacity to reproduce the observations, and could capture the temporal and spatial variations of temperature, radiation, humidity, wind speed, wind direction, $PM_{2.5}$ concentration, and O_3 concentration. The performance of the two-way online simulation was slightly better than that of the one-way online simulation. The aerosol direct effects on the meteorology and air quality were calculated by taking the differences between the results of the two-way online simulation and the one-way online simulation. Over four target countries, namely Laos, Cambodia, Thailand, and Vietnam, the aerosol direct effects moderately decreased the shortwave radiation, temperature, planetary boundary layer (PBL) height, and wind speed by −10.98 W/m^2 (−5.17%), −0.21 °C (−0.85%), −27.25 m (−6.13%), and −0.03 m/s (−1.29%), respectively. These percentages were −17.80 W/m^2 (−7.71%), −0.39 °C (−1.67%), −48.33 m (−8.89%), and −0.06 m/s (−2.01%) during the dry season, and −4.31 W/m^2 (−2.22%), −0.03 °C (−0.12%), −6.71 m (−1.92%), and −0.01 m/s (−0.50%) during the wet season, respectively. Consequently, the meteorological response to direct effects led to changes in the ground-level $PM_{2.5}$ and O_3 concentrations. The $PM_{2.5}$ concentration was found to increase by +1.21 μg/m^3 (+5.36%) and the O_3 concentration was found to decrease by −0.40 ppb (−1.26%) over the entire year. For each season, the $PM_{2.5}$ concentration increased by +2.09 μg/m^3 (+6.75%) during the dry season and +0.15 μg/m^3 (+1.42%) during the wet season. The O_3 concentration decreased by −0.96 ppb (−2.41%) during the dry season and slightly increased by +0.13 ppb (+0.55%) during the wet season. The direct effects were large during high $PM_{2.5}$ polluted periods and locations. A correlation matrix clarified that the increasing effect of aerosol on the $PM_{2.5}$ concentration was attributed to the decrease in the above-mentioned meteorological variables. The increase or decrease in the O_3 concentration depended on the responses of the atmospheric dynamics as well as the photolysis rates.