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Analysis of Influential Factors for the Relationship between $PM_{2.5}$ and AOD in Beijing

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Relationship between aerosol optical depth (AOD) and $PM_{2.5}$ is often investigated in order to obtain surface $PM_{2.5}$ from satellite observation of AOD with a broad area coverage. However, various factors could affect the AOD-$PM_{2.5}$ regressions. Using both ground and satellite observations in Beijing from 2011 to 2015, this study analyzes the influential factors including aerosol type, relative humidity (RH), atmospheric boundary layer height (PBLH), wind speed and direction, and the vertical structure of aerosol distribution. The ratio of $PM_{2.5}$ to AOD, which is defined as η, and the square of their correlation coefficient (R^2) have been examined. It shows that η varies from 54.32 to 183.14, 87.32 to 104.79, 95.13 to 163.52 and 1.23 to 235.08 $\mu g/m^3$ with aerosol type in four seasons respectively. η is smaller for scattering-dominant aerosols than for absorbing-dominant aerosols, and smaller for coarse mode aerosols than for fine mode aerosols. Both RH and PBLH affect the η value significantly. The higher the RH, the larger the η, and the higher the PBLH, the smaller the η. For AOD and $PM_{2.5}$ data with the correction of RH and PBLH compared to those without, R^2 of monthly averaged $PM_{2.5}$and AOD at 14:00 LT increases from 0.63 to 0.76, and R^2 of multi-year averaged $PM_{2.5}$and AOD by time of day increases from 0.1 to 0.93, 0.24 to 0.84, 0.85 to 0.91 and 0.84 to 0.93 in four seasons respectively. Wind direction is a key factor to the transport and spatial-temporal distribution of aerosols originated from different sources with distinctive physicochemical characteristics. Similar to the variation of AOD and $PM_{2.5}$, η also decreases with the increasing surface wind speed, indicating that the contribution of surface $PM_{2.5}$ concentrations to AOD decreases with surface wind speed. The vertical structure of aerosol exhibits a remarkable change with seasons, with most particles concentrated within about 500 m in summer and within 150 m in winter. Compared to the AOD of the whole atmosphere, AOD below 500 m has a better correlation with $PM_{2.5}$, for which R^2 is 0.77. This study suggests that all the above influential factors should be considered when we investigate the $PM_{2.5}$-AOD relationships.