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Two Methods to Derive Ground-level Concentrations of PM2.5 with Improved Accuracy in the North China, Calibrating MODIS AOD and CMAQ Model Predictions

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Reliable and accurate characterizations of ground-level PM2.5 concentrations are essential to understand pollution sources and evaluate human exposures etc. Monitoring network could only provide direct point-level observations at limited locations. At the locations without monitors, there are generally two ways to estimate the pollution levels of PM2.5. One is observations of aerosol properties from the satellite-based remote sensing, such as Moderate Resolution Imaging Spectroradiometer (MODIS) aerosol optical depth (AOD). The other one is from deterministic atmospheric chemistry models, such as the Community Multi-Scale Air Quality Model (CMAQ). In this study, we used a statistical spatio-temporal downscaler to calibrate the two datasets to monitor observations to derive fine-scale ground-level concentrations of PM2.5 with improved accuracy. We treated both MODIS AOD and CMAQ model predictions as biased proxy estimations of PM2.5 pollution levels. The downscaler proposed a Bayesian framework to model the spatially and temporally varying coefficients of the two types of estimations in the linear regression setting, in order to correct biases. Especially for calibrating MODIS AOD, a city-specific linear model was established to fill the missing AOD values, and a novel interpolation-based variable, i.e. PM2.5 Spatial Interpolator, was introduced to account for the spatial dependence among grid cells. We selected the heavy polluted and populated North China as our study area, in a grid setting of 81×81 12-km cells. For the evaluation of calibration performance for retrieved MODIS AOD, the R2 was 0.61 by the full model with PM2.5 Spatial Interpolator being presented, and was 0.48 with PM2.5 Spatial Interpolator not being presented. The constructed AOD values effectively predicted PM2.5 concentrations under our model structure, with R2=0.78. For the evaluation of calibrated CMAQ predictions, the R2 was 0.51, a little less than that of calibrated AOD. Finally we obtained two sets of calibrated estimations of ground-level PM2.5 concentrations with complete spatial coverage. By comparing the two datasets, we found that the prediction from AOD have a little smoother texture than that from CMAQ. The former also predicted larger heavy pollution area in the southern Hebei province than the latter, but in a small margin. In general, they have pretty similar spatial patterns, indicating the reliability of our data fusion method. In summary, the statistical spatio-temporal downscaler could provide improvements on MODIS AOD and CMAQ's predictions on PM2.5 pollution levels. Future work would focus on fusing three datasets, as aforementioned monitor observations, MODIS AOD and CMAQ predictions, to derive predictions of ground-level PM2.5 pollution levels with even increased accuracy.