**Estimating ground-level particulate matter concentrations using satellite-based data: A review**

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Table S1. Summary of the reviewed papers in this study.

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| --- | --- | --- | --- | --- | --- |
| **Authors (year)** | **Study area (nation scale)** | **Satellite dataa  (AOD)** | **Methodb** | **Resultsc** | **Target** |
| Gupta and Christopher (2009a) | U.S. | MODIS | ANN | R = 0.78 (daily) | PM2.5 |
| Gupta and Christopher (2009b) | U.S. | MODIS | MLR | R = 0.51-0.73 (daily) | PM2.5 |
| Tian and Chen (2010) | Canada | MODIS | Nonlinear empirical model | R2 = 0.65, RMSE = 6.1 (hourly) | PM2.5 |
| van Donkelaar et al. (2010) | Global | MODIS, MISR | CTM | R = 0.77 (daily) | PM2.5 |
| Wang et al. (2010) | China | MODIS | Vertical correction model | PM10: R2 = 0.47 PM2.5: R2 = 0.47(daily) | PM10, PM2.5 |
| Kloog et al. (2011) | U.S. | MODIS | GAMM | 10CV-R2 = 0.81-0.83 (daily) | PM2.5 |
| van Donkelaar et al. (2011) | Russia | MODIS | CTM | R2 = 0.85 (daily) | PM2.5 |
| Mao et al. (2012) | U.S. | MODIS | LUR | CV-R2 = 0.58 (monthly) | PM2.5 |
| Chang, Hu, and Liu (2013) | U.S. | MODIS | MEM | CV-R2 = 0.78, RMSE = 3.61 (daily) | PM2.5 |
| Hu et al. (2013) | U.S. | MODIS | GWR | R = 0.94, RMSPE = 2.32-2.37 CV-R = 0.82-0.84, RMSPE = 3.81-4.14 (daily) | PM2.5 |
| Nordio et al. (2013) | Italy | MODIS | 4-stage MEM | 10CV-R2 = 0.79 (daily) | PM10 |
| Sorek-Hamer et al. (2013) | U.S. | MODIS, OMI | LR, MARS, GAM | R2 = 0.2-0.71, RMSE = 6.70-6.83 (daily) | PM2.5 |
| Chen et al. (2014) | China | Landsat OLI/TIRS | MLR | R2 = 0.72, RMSE = 3.32 | PM2.5 |
| Chudnovsky et al. (2014) | U.S. | MODIS MAIAC | MEM | R2 = 0.89 (daily) | PM2.5 |
| Hu et al. (2014) | U.S. | MODIS MAIAC | 2-stage model | CV-R2 = 0.67 | PM2.5 |
| Kloog et al. (2014) | U.S. | MODIS MAIAC | MEM | 10CV-R2 = 0.88, RMSE = 2.33 (daily) | PM2.5 |
| Ma et al. (2014) | China | MODIS | GWR | R2 = 0.71, RMSE = 29.58 (daily) | PM2.5 |
| Saleh and Hasan (2014) | Iraq | Landsat OLI | MLR | R = 0.83, RMSE = 11.84 | PM10 |
| Saunders, Kahl, and Ghorai (2014) | U.S. | MODIS | MLR | R2 = 0.51 (daily) | PM2.5 |
| Song et al. (2014) | China | MODIS | GWR | Mean relative accuracy = 88.6% (daily) | PM2.5 |
| Chitranshi, Sharma, and Dey (2015) | India | MODIS | Logistic regression | R = 0.76, RSE = 8.86 % (daily) | PM10 |
| Geng et al. (2015) | China | MODIS, MISR | CTM | R = 0.74 (monthly) | PM2.5 |
| Kloog et al. (2015) | Israel | MODIS MAIAC | MEM | PM10: CV-R2 = 0.79 PM2.5: CV-R2 = 0.72 (daily) | PM10, PM2.5 |
| Li et al. (2015) | China | MODIS | MEM | R2 = 0.847, RMSE = 13.88 CV-R2 = 0.796, RMSE = 16.04 (daily) | PM2.5 |
| Lin et al. (2015) | China | MODIS | Nonlinear empirical model | R = 0.76 (monthly) | PM2.5 |
| Luo et al. (2015) | China | Landsat ETM+ | MLR | R2 = 0.55 | PM10 |
| van Donkelaar et al. (2015) | U.S. | MODIS | CTM-GWR | R2 = 0.82 (monthly) | PM2.5 |
| Xie et al. (2015) | China | MODIS | MEM | CV-R2 = 0.75-0.79 (daily) | PM2.5 |
| Xu et al. (2015) | China | GOCI | CTM | RMSE = 13.1 (for monthly) | PM2.5 |
| You, Zang, Zhang, et al. (2015) | China | MODIS | GWR | R2 = 0.82, RMSE = 15.30 CV-R2 = 0.77, RMSE = 16.91 (daily) | PM10 |
| You, Zang, Pan, et al. (2015) | China | MODIS, MISR | GAM | R = 0.82-0.85, RMSE = 32.95-40.88 (daily) | PM2.5 |
| Zhang and Li (2015) | China | MODIS, MISR | Vertical correction model | R = 0.5, MSE = 64 (hourly) | PM2.5 |
| Bai et al. (2016) | China | MODIS SARA | GTWR | CV-R2 = 0.87, RMSE = 21.77 (daily) | PM2.5 |
| Di et al. (2016) | U.S. | MODIS MAIAC | 2-stage NN | CV-R2 = 0.84, RMSE = 2.94 (annual) | PM2.5 |
| Fang et al. (2016) | China | MODIS | TSAM | 10CV-R2 = 0.80 (annual) | PM2.5 |
| Ghotbi, Sotoudeheian, and Arhami (2016) | Iran | MODIS | MEM | 10CV-R2 = 0.73, RMSE = 16.91 (daily) | PM10 |
| Lee, Chatfield, and Strawa (2016) | U.S. | MODIS | MEM | CV-R2 = 0.66, RMSE = 5.69 (daily) | PM2.5 |
| Li et al. (2016) | China | MODIS | Vertical correction model | Mean error = 38 (daily) | PM2.5 |
| Ma, Hu, et al. (2016) | China | MODIS | Hybrid MEM-GAM | R2 = 0.73 (monthly) | PM2.5 |
| Ma, Liu, et al. (2016) | China | MODIS | MEM | 10CV-R2 = 0.671 DOY-based-CV-R2 = 0.339 (daily) | PM2.5 |
| Meng et al. (2016) | China | MODIS | MEM | 10CV-R2 = 0.87, RMSE = 19.2 (daily) | PM10 |
| van Donkelaar et al. (2016) | Global | MODIS, MODIS MAIAC, MISR, SeaWiFS | CTM | R2 = 0.85, CV-R2 = 0.81 (annual) | PM2.5 |
| Wu et al. (2016) | China | VIIRS | 2-stage GWR | CV-R2 = 0.72, RMSE = 19.29 (daily) | PM2.5 |
| You, Zang, Zhang, Zhang, et al. (2016) | China | MODIS | GAM | R2 = 0.45 (for daily) | PM10 |
| You, Zang, Zhang, Li, and Wang (2016) | China | MODIS, MISR | GWR | CV-R2 = 0.76-0.81, RMSE = 22.26-27.46 (daily) | PM2.5 |
| You, Zang, Zhang, Li, Pan, et al. (2016) | China | MODIS | GWR | CV-R2 = 0.79, RMSE = 18.6 (daily) | PM2.5 |
| Zhang, Gong, et al. (2016) | China | MODIS | GWR | CV-R2 = 0.87 (daily) | PM2.5 |
| Zhang, Liu, et al. (2016) | China | MODIS | Semi-physical GWR | CV-R2 = 0.80-0.86 (daily) | PM2.5 |
| Zheng et al. (2016) | China | MODIS | MEM | LOOCV-R2 = 0.77-0.80, RMSE = 12.47-23.07 (daily) | PM2.5 |
| Zou et al. (2016) | China | MODIS SARA | GWR | 10CV-RMSE = 11 (annual) | PM2.5 |
| Gong et al. (2017) | China | MODIS | MEM | CV-R2 = 0.77 RMSE = 13.11 (daily) | PM2.5 |
| Guo et al. (2017) | China | MODIS | GTWR | CV R2 = 0.58, RMSE = 30.81 (daily) | PM2.5 |
| Hu et al. (2017) | U.S. | MODIS | RF | CV-R2 = 0.80, RMSE = 2.83 (daily) | PM2.5 |
| Jiang et al. (2017) | China | MODIS | GWR | CV-R2 = 0.74-0.79 (daily) | PM2.5 |
| Li, Shen, Yuan, et al. (2017) | China | MODIS | Geoi-DBN | R2 = 0.88, RMSE = 13.03 (daily) | PM2.5 |
| Li, Shen, Zeng, et al. (2017) | China | MODIS | GRNN | CV-R = 0.82, RMSE = 20.93 (daily) | PM2.5 |
| Lv et al. (2017) | China | MODIS | Bayesian linear regression model | 10CV-R2 = 0.58 LOCCV-R2 = 0.47 (daily) | PM2.5 |
| Mao, Shen, and Feng (2017) | China | MODIS | MLP | 12h forecast RMSE = 45.29 | PM2.5 |
| Pereira et al. (2017) | Australia | MODIS | MEM | LOOCV-R2 = 0.46, RMSE = 6 (daily) | PM10 |
| Stafoggia et al. (2017) | Italy | MODIS MAIAC | 4-stage MEM | 10CV-R2 = 0.72, RMSPE = 9.0 (stage 3) (daily) | PM10 |
| Xiao et al. (2017) | China | MODIS MAIAC | MEM-GAM | R2 = 0.77 (for daily) 10CV-R2 = 0.73-0.81, RMSE = 18-25 (for each year) | PM2.5 |
| Yan et al. (2017) | China | MODIS | Nonlinear empirical model | R2 = 0.64, RMSE = 18.9 (hourly) | PM2.5 |
| Yang et al. (2017) | China | MODIS, MISR, SeaWiFS | LUR | R2 = 0.707-0.895, LOOCV-R2 = 0.588-0.872, LOOCV-RMSE = 2.754-5.118 (annual) | PM2.5 |
| Yeganeh et al. (2017) | Australia | OMI | ANFIS, SVM, BPANN | R2 = 0.61-0.84, RMSE = 0.94-1.57, CV-R2 = 0.54-0.81, CV-RMSE = 1.79-2.11 (monthly) | PM2.5 |
| Zhan et al. (2017) | China | MODIS MAIAC | GW-GBM | CV-R2 = 0.74-0.76, RMSE = 23.0-24.3 (daily) | PM2.5 |
| Zou et al. (2017) | China | MODIS | GAM | CV-R2 = 0.78-0.90 (seasonally) | PM2.5 |
| Brokamp et al. (2018) | U.S. | MODIS | RF | CV-R2 = 0.91, RMSE = 2.22 (daily) | PM2.5 |
| Chen, Li, et al. (2018) | China | MODIS | RF | 10CV-R2 = 0.83, RMSE = 18.0 (daily) | PM2.5 |
| Chen, Zhang, et al. (2018) | China | MODIS | GAMM | CV-R2 = 0.81 (daily) | PM2.5 |
| Chen, Knibbs, et al. (2018) | China | MODIS | GAM | 10CV-R2 = 0.59 (for daily) | PM1 |
| de Hoogh et al. (2018) | Switzerland | MODIS MAIAC | 4-stage MEM-GAMM-SVR | R2 = 0.784-0.912, RMSE = 2.874-4.470 (daily) 10CV-R2 = 0.642-0.816, 10CV-RMSE = 3.710-5.783 (daily) | PM2.5 |
| Fu et al. (2018) | China | VIIRS | MEM | CV-R2 = 0.92 (daily) | PM2.5 |
| Gao et al. (2018) | China | Own AOD based on MODIS | Vertical correction model | R = 0.78 (daily) | PM2.5 |
| Geng, Murray, Tong, et al. (2018) | U.S. | MODIS MAIAC | Bayesian ensemble model | 10CV-R2 = 0.66, RMSE = 2 (daily) | PM2.5 |
| Geng, Murray, Chang, et al. (2018) | U.S. | MODIS MAIAC | 2-stage Bayesian ensemble | 10CV-R2 = 0.82, RMSE = 3.01 (daily) | PM2.5 |
| Han et al. (2018) | China | MODIS MAIAC | MEM | CV-R2 = 0.87-0.93 (daily) | PM2.5 |
| He and Huang (2018b) | China | MODIS | GTWR | R2 = 0.80, RMSE = 18 (daily) | PM2.5 |
| He and Huang (2018a) | China | MODIS | GTWR, i-GTWR | GTWR: CV-R2 = 0.82 i-GTWR: CV-R2 = 0.46(daily) | PM2.5 |
| Huang et al. (2018) | China | MODIS MAIAC | RF | CV-R2 = 0.88 (monthly) | PM2.5 |
| Jiang and Christakos (2018) | China | MODIS | GBM & BME | 10CV-R2 = 0.86, RMSE = 14.37 (daily) | PM2.5 |
| Jung, Hwang, and Chen (2018) | Taiwan | MODIS | MEM | CV-R2 = 0.66, RMSE = 12.9-14.0 (daily) | PM2.5 |
| Li, Zhang, et al. (2018) | China | MODIS MAIAC | MEM | CV-R2 = 0.87 R2 = 0.75 (for independent day) (daily) | PM2.5 |
| Li, Xue, et al. (2018) | China | MODIS MAIAC | SPSEMCA | R = 0.7-0.75, RMSE = 43.38-58.75 (daily) | PM2.5 |
| Li, Chen, et al. (2018) | China | MODIS | OR, DT, RF, SVM | 5CV-R = 0.68-0.85, RMSE = 33.90-52.63 (daily) | PM2.5 |
| Li, Ma, et al. (2018) | China | MODIS MAIAC | LUR | R2 = 0.93, RMSE = 4.10 (yearly) | PM2.5 |
| Lin et al. (2018) | China | MODIS | Vertical correction model | R = 0.78, RMSE = 19.3 (monthly) | PM2.5 |
| Pang et al. (2018) | China | GOCI, VIIRS | DA | ER = 8% (hourly) | PM2.5 |
| Qin et al. (2018) | China | MODIS | GTWR | 10CV-R2 = 0.74, RMSE = 13.02 (daily) | PM2.5 |
| Shi et al. (2018) | Hong Kong | MODIS | GTWR | LOOCV-R2 = 0.654, RMSE = 9.641 (annual) | PM2.5 |
| Soni, Payra, and Verma (2018) | India | MODIS | LR, MLR, log-LR | R = 0.8 (daily) | PM10 |
| Xiao, Lang, and Christakos (2018) | China | MODIS | BME-GWR | CV-R2 = 0.883, RMSE = 11.39 (monthly) | PM2.5 |
| Xu et al. (2018) | Canada | MODIS | MLR, BRNN, SVM, LASSO, MARS, RF, XGB, DT | 10CV-R2 = 0.22-0.49, RMSE = 2.64-3.24 (monthly) | PM2.5 |
| Yao et al. (2018) | China | MODIS, VIIRS | Time fixed effect regression | R2 = 0.71-0.76, CV-R2 = 0.66-0.72 (daily) | PM2.5 |
| Zang et al. (2018) | China | AHI | MLR, MEM, BPNN, GRNN, PCA-GRNN | R2 = 0.23-0.65, RMSE = 22-32.8 (hourly) | PM1 |
| Zhai et al. (2018) | China | MODIS | BSR-PCA-GWR | CV-adjusted-R2 = 0.860, RMSE = 7.717 (annual) | PM2.5 |
| Zhang, Di, et al. (2018) | China | MODIS | RF | R2 = 0.86 (for daily) | PM2.5 |
| Zhang, Zhu, et al. (2018) | China | GF-1 | MEM | site CV-R2 = 0.88-0.92 DOY CV-R2 = 0.54-0.58 (every 4 days) | PM2.5 |
| Zhang, Wang, et al. (2018) | China | MODIS | GAMM | PM10: R2 = 0.71, RMSE = 3.86, CV-R2 = 0.62 PM2.5: R2 = 0.87, RMSE = 12.41, CV-R2 = 0.85 (monthly) | PM10, PM2.5 |
| Zhang, Chu, et al. (2018) | U.S. | MODIS MAIAC | MEM | 10CV-R2 = 0.63-0.69 (daily for each year) | PM2.5 |
| Bai et al. (2019) | China | MODIS, MISR, SeaWiFS | GWR | CV R2 = 0.75, RMSE = 13.59 (monthly) | PM2.5 |
| Bi et al. (2019) | U.S. | MODIS MAIAC | RF | 10CV-R2 = 0.82, RMSE = 2.16 (daily) | PM2.5 |
| Chen et al. (2019) | China | MODIS | XGB | CV-R2 = 0.86, RMSE = 14.98 (daily) | PM2.5 |
| Chu and Bilal (2019) | Taiwan | MODIS | GTWR | R2 = 0.83, RMSE = 7.9 (daily) | PM2.5 |
| Di et al. (2019) | U.S. | MODIS | 2-stage ensemble | 10CV-R2 = 0.86, 10CV-RMSE = 2.786 (daily) | PM2.5 |
| Goldberg et al. (2019) | U.S. | MODIS MAIAC | MLR | CV-R2 = 0.75 (daily) | PM2.5 |
| Han and Tong (2019) | China | MODIS MAIAC | MEM | R2 = 0.81, RMSPE = 15.47 (daily) | PM2.5 |
| Hu et al. (2019) | China | MODIS | STRK | CV-R2 = 0.87, RMSE = 16.55 (daily) | PM2.5 |
| Hua et al. (2019) | China | MODIS | 2-stage GAM | 10CV-R2 = 0.78, RMSE = 19.177 (daily) | PM2.5 |
| Kumar et al. (2019) | U.S. | MODIS NNR | DA | R = 0.67 (daily) | PM2.5 |
| Li and Zhang (2019) | China | MODIS | RF | 10CV-R2 = 0.933, RMSE = 16.315 (daily) | PM2.5 |
| Liu, Weng, and Li (2019) | China | Own AOD based on AHI, AHI | RF | R2 = 0.86, RMSE = 17.3 (hourly) | PM2.5 |
| Nabavi, Haimberger, and Abbasi (2019) | Iran | MODIS, MODIS MAIAC | RF | R2 = 0.68, RMSE = 17.52 (daily) | PM2.5 |
| Park et al. (2019) | South Korea | GOCI | RF | PM10: R2 = 0.78, RMSE = 17.08 PM2.5: R2 = 0.73, RMSE = 8.25 (hourly) | PM10, PM2.5 |
| Sarafian et al. (2019) | U.S. | MODIS MAIAC | MEM, GMRF | 10CV-R2 = 0.80-0.83, RMSE = 2.42-2.68 (daily) | PM2.5 |
| Sathe et al. (2019) | India | MODIS | MLR | R = 0.61, RMSE = 77.89 (hourly) | PM2.5 |
| Stafoggia et al. (2019) | Italy | MODIS MAIAC | RF-LUR | PM10: R2 = 0.84 PM2.5: R2 = 0.86 (daily) | PM10, PM2.5 |
| Sun et al. (2019) | China | AHI | DNN | CV-R2 = 0.84, CV-RMSE = 19.9 (hourly) | PM2.5 |
| van Donkelaar et al. (2019) | U.S. | MODIS, MODIS MAIAC, MISR, SeaWiFS | CTM | R2 = 0.76 (annual) | PM2.5 |
| Wang and Sun (2019) | China | MODIS | DNN | R2 = 0.87, RMSE = 27.11 (daily) | PM2.5 |
| Wang, Mao, et al. (2019) | China | AHI | MEM-BT | 10CV-R2 = 0.80, RMSE = 15.4 (hourly) | PM1 |
| Wang, Zhao, et al. (2019) | China | MODIS | S-BPNN | 10CV-R2 = 0.89, 10CV-RMSE = 5.8 (daily) | PM2.5 |
| Wei et al. (2019) | China | MODIS MAIAC | STRF | 10CV-R2 = 0.85, RMSE = 15.57 (daily) | PM2.5 |
| Xie et al. (2019) | China | MODIS SARA | MEM | 10CV-R2 = 0.82, RMSE = 31.88 (daily) | PM2.5 |
| Xue et al. (2019) | China | MODIS | 2-stage HD Expansion-GAM | LOYCV-R2 = 0.55 (daily) | PM2.5 |
| Yang, Xu, and Jin (2019) | China | MODIS | MEM-SVR model | R2 = 0.77, RMSE = 9.51 (daily) | PM2.5 |
| Yao et al. (2019b) | China | VIIRS | 2-stage TFER-GWR | 10CV-R2 = 0.60 (daily) | PM2.5 |
| Yao et al. (2019a) | China | VIIRS | 2-stage TFER-GWR | 10CV-R2 = 0.81 (daily) | PM2.5 |
| Zang et al. (2019) | China | AHI | MLR, GRNN, PCA-integrated GRNN | R2 = 0.21-0.74, RMSE = 19-33.3 (hourly) | PM1 |
| Zhang et al. (2019) | China | AHI | MEM | 10CV-R2 = 0.74-0.84 (hourly) | PM2.5 |
| Zeydan and Wang (2019) | Turkey | MODIS | MLR | R2 = 0.61, RMSE = 0.337 (daily) | PM2.5 |

a Instrument: Advanced Himawari Imager (AHI), Gaofen-1 (GF-1), Geostationary Ocean Color Imager (GOCI), Multi-angle Imaging SpectroRadiometer (MISR), Moderate Resolution Imaging Spectroradiometer (MODIS), MODIS Multi-Angle Implementation of Atmospheric Correction (MODIS MAIAC), MODIS Neural Net Retrievals (MODIS NNR), MODIS Simplified Aerosol Retrieval Algorithm (MODIS SARA), Ozone Monitoring Instrument (OMI), Sea-viewing Wide Field-of-View Sensor (SeaWiFS), Visible Infrared Imaging Radiometer Suite (VIIRS)

b Methods - Adaptive Neuro-Fuzzy Inference System (ANFIS), Bayesian Maximum Entropy (BME), Back-Propagation Artificial Neural Network (BPANN), Back-Propagation Neural Network (BPNN), Bayesian Regularized Neural Network (BRNN), Best Subset Regression (BSR), Bagged Trees (BT), Data Assimilation (DA), Deep Belief Network (DBN), Deep Neural Network (DNN), Decision Trees (DT), Gaussian Markov Random Field (GMRF), Generalized Regression Neural Network (GRNN), Least Absolute Shrinkage and Selection Operator (LASSO), Multivariate Adaptive Regression Splines (MARS), Orthogonal Regression (OR), Principal Component Analysis (PCA), Random Forest (RF), Spatial Back-Propagation Neural Network (S-BPNN), Specific Particle Swarm Extinction Mass Conversion Algorithm (SPSEMCA), Space-Time Random Forest (STRF), Spatiotemporal Regression Kriging (STRK), Support Vector Machine (SVM), Time Fixed Effects Regression (TFER), Timely Structure Adaptive Modeling (TSAM), Extreme Gradient Boost (XGB)

c Statistics in results - Correlation coefficient (R), Relative Standard Error (RSE), Coefficient of determination (R2), Root Mean Square Error (RMSE; μg/m3), Root Mean Square Percent Error(RMSPE; μg/m3), Error Reduction (ER), Cross-Validation (CV), 5-fold Cross-Validation (5CV), 10-fold Cross-Validation (10CV), Leave-One-Out Cross-Validation (LOOCV), Leave-One-City-Out-Cross Validation (LOCCV), Leave-One-Year-Out-Cross Validation (LOYCV)

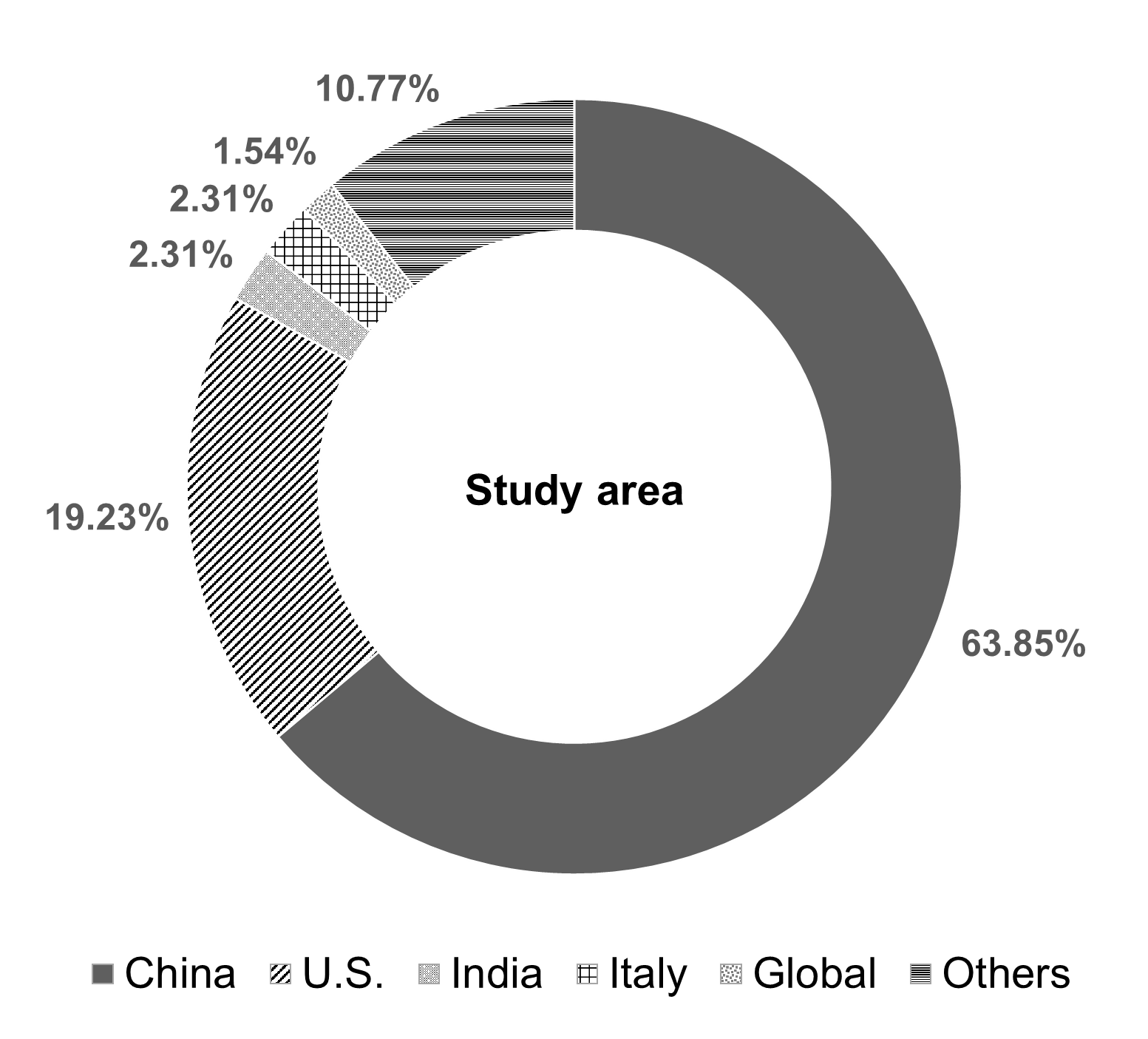


Figure S1. The distribution of study areas in the reviewed papers that predicted ground PM concentrations using satellite AOD as the main input predictor during the past 10 years.

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Chen, Gongbo, Shanshan Li, Luke D Knibbs, NAS Hamm, Wei Cao, Tiantian Li, Jianping Guo, Hongyan Ren, Michael J Abramson, and Yuming Guo. 2018. "A machine learning method to estimate PM2.5 concentrations across China with remote sensing, meteorological and land use information."  *Science of the Total Environment* 636:52-60.

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