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Prediction of Aerosol Optical Depth in West Asia: Machine Learning Methods versus Numerical Models

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Dust-prone areas of West Asia are releasing increasingly large amounts of dust particles during warm months. Because of the lack of ground-based observations in the region, this phenomenon is mainly monitored through remotely sensed aerosol products. The recent development of mesoscale Numerical Models (NMs) has offered an unprecedented opportunity to predict dust emission, and, subsequently Aerosol Optical Depth (AOD), at finer spatial and temporal resolutions. Nevertheless, the significant uncertainties in input data and simulations of dust activation and transport limit the performance of numerical models in dust prediction. The presented study aims to evaluate if machine-learning algorithms (MLAs), which require much less computational expense, can yield the same or even better performance than NMs. Deep blue (DB) AOD, which is observed by satellites but also predicted by MLAs and NMs, is used for validation. We concentrate our evaluations on the over dry Iraq plains, known as the main origin of recently intensified dust storms in West Asia. Here we examine the performance of four MLAs including Linear regression Model (LM), Support Vector Machine (SVM), Artificial Neural Network (ANN), Multivariate Adaptive Regression Splines (MARS). The Weather Research and Forecasting model coupled to Chemistry (WRF-Chem) and the Dust REgional Atmosphere Model (DREAM) are included as NMs. The MACC aerosol re-analysis of European Centre for Medium-range Weather Forecast (ECMWF) is also included, although it has assimilated satellite-based AOD data. Using the Recursive Feature Elimination (RFE) method, nine environmental features including soil moisture and temperature, NDVI, dust source function, albedo, dust uplift potential, vertical velocity, precipitation and 9-month SPEI drought index are selected for dust (AOD) modeling by MLAs. During the feature selection process, we noticed that NDVI and SPEI are of the highest importance in MLAs predictions. The data set was divided into a training (2003-2010) and a testing (2011-2013) subset. The evaluation using the two subsets shows that ANN outperformed all other MLAs and NMs. Verified to monthly mean MODIS DB AOD, ANN yielded a Spearman correlation coefficient (SCC) of 0.74, whereas SCC of 0.71 was allotted to WRF-chem simulations, as the most successful NM. In terms of simulation accuracy, SVM and MARS have yielded the lowest bias (-0.001) and RMSE (0.16). DREAM showed the poorest performance with a SCC of 0.52, a bias of -0.17 and a RMSE of 0.29.