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Understanding driving factors of ground PM10 concentrations using satellite AOD and a machine learning approach

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This contribution quantifies the driving factors of air pollution using machine learning, and sets a basis for understanding regional patterns using satellite-based remote sensing.
Discussions on effective measures to reduce exposure to air pollution are ongoing as the actual effects of those measures are not always clear. This is because the concentration of near-ground particulate matter (PM) depends on various factors that influence regional aerosol transport and local accumulation, and will superimpose the effects of measures taken to reduce PM concentrations. To better constrain adequate measures to improve air quality and to understand driving factors of elevated particle concentrations, it is crucial to understand the variability of PM related to ambient meteorological factors, such as wind speed, wind direction, planetary boundary layer and precipitation.
This contribution proposes the use of Gradient Boosted Regression Trees (GBRT) to understand driving factors in spatiotemporal variations of PM10 concentrations. GBRT is a ensemble learning technique similar to the Random Forest approach. It sequentially adds predictors to an ensemble, with each new predictor correcting its predecessor. Each new predictor is fitted to the predecessor's previous residual error and tries to minimize it. In this study, the GBRT model is trained on hourly mean PM10 concentrations [μg/m^3] in Germany, taken from the German Environmental Office. Further input parameters include satellite observations from the Moderate Resolution Imaging Spectroradiometer (MODIS) and others, model output from the European Centre for Medium-Range Weather Forecasts (ECMWF) and station data from the German Meteorological Service (Deutscher Wetterdienst, DWD). AOD observations from the MODIS-based high-resolution Multi-Angle Implementation of Atmospheric Correction (MAIAC) AOD algorithm are considered.
The GBRT allows to isolate the individual contribution of one input feature and relate it to PM10, taking into account variations of other input features. This way, the multivariate problem of air pollution is constrained and individual influences can be investigated. The model generally performs well (R^2=0.73, RMSE=8.2μg/m^2). Results show a high importance of the boundary layer height (BLH), precipitation and winds in the east-west direction. Situations with a low BLH and lacking precipitation generally cause the model to produce elevated PM10 concentrations. When eastern winds prevail, the model tends to estimate higher PM10 concentrations than for situations dominated by western winds. The importance of vegetation, here approached by the NDVI, appears to be low.