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Importance of satellite observations for high-resolution mapping of near-surface NO_2 by machine learning

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Nitrogen oxides (NO_x = NO+ NO_2) are harmful to human health and are precursors of other key air pollutants like ozone (O_3) and particulate matter (PM). Since the lifetime of NO_x is short and its main sources are anthropogenic emissions like fuel combustion from traffic and industry, near-surface NO_x concentrations are highly variable in space and time. To assess the impact of NO_2 on public health, maps of high spatial and temporal resolution are critical. In this study, we present hourly near-surface NO_2 concentrations at 100 m resolution for Switzerland and northern Italy that are produced using machine learning, specifically an extreme gradient-boosted tree ensemble. The model was trained with *in situ* observations from European Air Quality e-Reporting data repositories (Airbase). Satellite NO_2 observations from the TROPospheric Monitoring Instrument (TROPOMI) were compiled together with land use data, meteorological data and topography as covariates. Evaluation against *in situ* observations not used for the training shows that the dynamic maps produced in this study reproduce the spatio-temporal variation in near-surface NO_2 concentrations with high accuracy (R^2 = 0.59, MAE = 7.69 µg/m^3). In addition, we demonstrate how public health studies can utilize such high-resolution maps for unbiased assessment of population exposure that can account for home addresses and mobility of individuals. Comparing the relative importance of the different covariates based on two different metrics, total information gain and averaged local feature importance, show a leading contribution of the TROPOMI observations despite their rather coarse resolution (3.5 km × 5.5 km) and daily update. TROPOMI NO_2 observations were particularly important for the quality of the NO_2 maps during periods of unusual NO_2 reductions (e.g., during COVID19 lockdown) and when detailed emission-related covariates like traffic density, that may not be available in other regions of the globe, were not included in the model. Since all data used in our study are publicly available, our approach can be readily extended to other regions in Europe or applied worldwide.