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A data-driven approach to quantifying urban evapotranspiration using remote sensing, footprint modeling, and deep learning

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An increasing number of urban residents are affected by the urban heat island effect and water scarcity as urbanization and climate change progress. Evapotranspiration (ET) is a key component of urban greening measures aimed at addressing these issues, yet methods to estimate urban ET have thus far been limited. In this study, we present a novel approach to model urban ET at a half-hourly scale by fusing flux footprint modeling, remote sensing (RS) and geographic information system (GIS) data, and artificial intelligence (AI). We investigated this approach with a two-year dataset (2018-2020) from two eddy flux towers in Berlin, Germany. Two AI algorithms (1D convolutional neural networks and random forest) were compared. The land surface characteristics contributing to ET measurements were estimated by combining footprint modeling with RS and GIS data, which included Normalized Difference Vegetation Index (NDVI) derived from the Harmonized Landsat and Sentinel-2 (HLS) NASA product and indicators of 3D urban structure (e.g. building height). The contribution of remote sensing and meteorological data to model performance was examined by testing four predictor scenarios: (1) only reference evapotranspiration (ETo), (2) ETo and RS/ GIS data, (3) meteorological data, and (4) meteorological and RS/ GIS data. The inclusion of GIS and RS data extracted using flux footprints improved the predictive accuracy of models. The best-performing models were then used to model ET values for the year 2019 and compute monthly and annual sums of ET. A variable importance analysis highlighted the importance of the NDVI and impervious surface fraction in modeling urban ET. The 2019 ET sum was considerably higher at the site surrounded by more urban vegetation (366 mm) than at the inner-city site (223 mm). The proposed method is highly promising for modeling ET in a heterogeneous urban environment and can bolster sustainable urban planning efforts.