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Assessing the water balance of paved surfaces with soil moisture observations

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Urbanization leads to dramatic changes in the water cycle and causes various negative hydrological impacts. Although paved surfaces often cover large parts of cities, little is still known about their role in the urban water balance. Our study tackles the following questions: Do paved surfaces contribute to an improvement of the urban water balance in terms of less surface runoff and higher evaporation? Which proportion of rainfall infiltrates into and evaporates from paved surfaces and what determines the magnitude of these fluxes?
Data was obtained from a sensor network of soil moisture probes installed in various depths beneath 32 urban surfaces within the city of Freiburg, Germany. For each plot, time series of soil moisture and temperature at different depths with a temporal resolution of 10 minutes are available since summer 2016.
We applied a model to describe the percolation from a defined soil layer. It assumes percolation to occur at gravity driven rates and uses the Burdine and Brooks-Corey model to describe the unsaturated hydraulic conductivity. For dry periods with low potential evaporation, we assume that percolation is the only process leading to a recession of soil moisture. Data of those periods was used to calibrate the percolation model, which then was applied to the entire time series. During the remaining rain-free periods, the difference between modeled and measured soil moisture recession was attributed to evaporation, whereas the difference during rainfall periods was attributed to infiltration. Hence, soil moisture gains and losses caused by infiltration, evaporation and percolation were calculated on an hourly time basis. The modeled losses and gains were converted to hydrological fluxes by multiplication with a representative soil layer thickness, which was obtained inversely from modelled infiltration gains during storm events that did not produce surface runoff. We assume that surface runoff is only produced by infiltration excess overland flow, which only occurs when precipitation intensity exceeds the site-specific infiltration rate. Furthermore, we obtained the initial loss for each surface.
With the derived model we calculated the hydrological fluxes of all paved surfaces from the soil moisture measurements. We use this to gain knew insights into the mechanisms governing these fluxes. Our results show that the evaporative water flux depends strongly on the soil water content and on potential evaporation rates. Furthermore, we can show that for most of the investigated surfaces, infiltration represents the biggest component of the annual surface water balance.