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Quantification of Urban Heat Island Distribution Using Multiple Linear Regression Models in Basel/Switzerland

Andreas Wicki, Eberhard Parlow, and Christian Feigenwinter
Department of Environmental Sciences, University of Basel, Basel, Switzerland

Increasing urban population and the expected increase in long lasting heat waves make the study of temperature distribution an important task in urban climatology, especially considering human health and heat stress. Excess heat during extreme heat waves is often underestimated because the official measurement stations are not representing the dense urban core with usually higher nocturnal temperatures. Additionally, it is not possible to maintain dense measurement networks to cover a large urban area. Therefore, the quantification of heat-distribution within the city is still rather qualitative and often limited to mobile measurements or point stations. Heat stress, known as one of the deadliest natural hazards, causes thousands of deaths during heat haves around the world every year. Thereby, only a small increase in nocturnal minimum temperature can have dramatic effects on the health of especially elderly and vulnerable people.
Urban climate is considerably depending on the transformation of former natural and pervious surfaces to strongly densified, paved and covered urban surfaces. This modification has dramatic effects on the exchange of mass, heat and momentum, which is reflected distinctly in the well-known urban heat island (UHI) effect. The factors influencing the development of the nocturnal UHI are evaluated during this study in detail and tested multitemporal within different spatial resolutions. Therefore, a multiple linear regression model is developed to determine the influence of urban structures and green spaces on the specific environment. For every step in time, the multiple regression equation is solved iteratively to find the dependence of air temperature - measured at different spots throughout the city and surroundings – on the underlying surface cover and morphology. The resulting coefficients are used to create comprehensive air temperature maps based on the input predictors. Results showed that different data sets are applicable for the prediction of the UHI distribution with comparable results, ideally run in a 200-m grid environment. Validation using random sampling indicated a RMSE below 1°C with an average around ∼0.5°C. The regression coefficients are varying within the nocturnal run with best results around 22:00 CET (>0.9).
The model was first tested and developed during a minor heat wave in August 2016. Average diurnal courses were used to determine a set of input predictors. After successful testing and further evaluation, it was applied during the long-lasting 2018 heat wave. Thereby, the nocturnal temperature distribution during several consecutive nights allowed to spot areas with an extraordinary heat load and inconvenient heat stress conditions.