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Past and future changes in the spatiotemporal distribution of heat stress in Madrid

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One relevant effect of urbanization is the modification of atmosphere-surface interactions, which modulate urban microclimate and human thermal comfort. To quantify the impact of heat on the human body, more comprehensive biometeorological indices, such as the Universal Thermal Climate Index (UTCI), are commonly employed accounting for not only air temperature influence but also the variability of other relevant weather variables such as wind speed, air humidity and radiation. The irregularity of urban morphology (e.g. building height and layout) across the city leads to high spatial heterogeneity of the micrometeorological variables, in particular on wind speed and solar radiation (e.g. shading effects). Therefore, analyzing the impact of urban geometry and the past changes in urban land cover on heat stress contributes to understanding the potential risks that urban residents might face considering the future urban growth and future climate.

The purpose of the present work is to investigate the impact of urban development and climate on outdoor thermal comfort in Madrid for summer weather conditions under past and future climate. A modeling study is conducted using the Weather, Research and Forecasting (WRF) model adapted to estimate the heat and momentum exchanges between buildings and atmosphere (BEP-BEM urban scheme), as well as the recent development incorporated into BEP-BEM to quantify heat stress through UTCI values and its subgrid variability. Past urban scenarios are performed considering the realistic urban expansion and morphology from 1970 to 2020, and the expected urban development is used for the future scenario. The model evaluation is conducted against observations showing an overall good performance of the model in predicting near-surface meteorological parameters. Even though the urban layout has barely changed in the center of Madrid over the last 50 years, results show an increase in the UTCI values due to the influence of the surrounding urban expansion. In addition, these results show the relative contribution of urbanization and climate effects on the heat stress changes across the city under the past and future climates.