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Downscaling Land Surface Temperature in an Urban Area: A Case Study for Hamburg, Germany

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Land surface temperature (LST) is an important parameter for the urban radiation and heat balance and a boundary condition for the atmospheric urban heat island (UHI). The increase in urban surface temperatures compared to the surrounding area (surface urban heat island, SUHI) has been described and analysed with satellite-based measurements for several decades. Besides continuous progress in the development of new sensors, an operational monitoring is still severely limited by physical constraints regarding the spatial and temporal resolution of the satellite data. Essentially, two measurement concepts must be distinguished: Sensors on geostationary platforms have high temporal (several times per hour) and poor spatial resolution ($\sim$ 5 km) while those on low earth orbiters have high spatial ($\sim$ 100-1000 m) resolution and a long return period (one day to several weeks).
To enable an observation with high temporal and spatial resolution, a downscaling scheme for LST from the Spinning Enhanced Visible Infra-Red Imager (SEVIRI) sensor onboard the geostationary meteorological Meteosat 9 to spatial resolutions between 100 and 1000 m was developed and tested for Hamburg in this case study. Therefore, various predictor sets (including parameters derived from multi-temporal thermal data, NDVI, and morphological parameters) were tested. The relationship between predictors and LST was empirically calibrated in the low resolution domain and then transferred to the high resolution domain. The downscaling was validated with LST data from the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) for the same time.
Aggregated parameters from multi-temporal thermal data (in particular annual cycle parameters and principal components) proved particularly suitable. The results for the highest resolution of 100 m showed a high explained variance (R^2 = 0.71) and relatively low root mean square errors (RMSE = 2.2 K). Larger predictor sets resulted in higher errors, because they tended to overfit. As expected the results were better for coarser spatial resolutions (R^2 = 0.80, RMSE = 1.8 K for 500 m). These results are similar or slightly better than in previous studies, although we are not aware of any study with a comparably large downscaling factor. A considerable percentage of the error is systematic due to the different viewing geometry of the sensors (the high resolution LST was overestimated about 1.3 K).
The study shows that downscaling of SEVIRI LST is possible up to a resolution of 100 m for urban areas and that multi-temporal thermal data are particularly suitable as predictors.