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Uncertainties in empirical downscaling of land surface temperature

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Land surface temperature (LST) is an important quantity in land surface-atmosphere interaction can in principal be well monitored by thermal infrared satellite remote sensing. Especially the diurnal temperature cycle (DTC) reveals information about relevant surface characteristics like thermal inertia. However, the acquisition is severely restricted by the orbital parameters of the sensors. The high temporal resolutions required for DTC monitoring can only be achieved from geostationary satellites at an altitude of about 36000 km and hence a poor spatial resolution (about 3 to 5 km depending on sensor and latitude). On the other hand, sensors in geostationary orbits with small swath width have higher spatial resolution (about 100 m) but a long revisit time of one to two weeks.
To close this gap, in this case study a downscaling scheme for LST from the SEVIRI sensor onboard the geostationary meteorological Meteosat Second Generation to spatial resolutions of down to 100 was developed and tested for Hamburg. Therefore, aggregated parameters from multi-temporal thermal data were applied like following. First, the predictors were upscaled to the coarse resolution, then a relationship between predictors and LST was empirically calibrated, which eventually was transferred to the higher resolution domain.
The downscaling was validated with LST data from ASTER and ETM+ for single times as well as longer time series of in situ LST measurements for single locations.
The validation with the ASTER data showed good results with a high R^2 of up tp 0.71 % and relatively low RMSE of about 2.2 K. The results with the ETM+ data were slightly worse due to the limited quality of the LST retrieval algorithm. Compared to the in situ data the DTC were essentially well represented but the downscaling did not improve the accuracy.

The proposed downscaling scheme can contribute to decrease the uncertainty in high spatial and temporal resolution LST estimation and overcome physical restrictions which prevent the application of such data in relevant fields like urban climatology. On the other hand, both systematic and statistical errors are introduced by the scheme.
The downscaling shows a considerable warm bias (1.3 K for ASTER, 0.7 K for ETM+) which partly can be explained by the viewing geometry (i.e. the geostationary satellite views more southern orientated slopes and facades). However, since first tests indicated that additional factors must be considered, the bias will be investigated in a more extensive study. Further systematic errors result from transferring the annual warming patterns to the diurnal cycle thus introducing annual effects like phenology and seasonal thermal stratification of water bodies.
Statistical errors are introduced by noise in both the SEVIRI data (accuracy of about 2 K) and the predictors, the geometrical precision and the approximation of the SEVIRI point spread function, and the linearity of the empirical model. To estimate magnitude and propagation of these errors, additional noise and locational offsets are added to the LST measurements and predictors in a sensitivity study.
Eventually, the comparison with the in situ data revealed that these also contain errors which raises the question whether direct measurements can really be considered as “ground truth” like common in remote sensing.