

Research paper:

**Characterizing Urban Heat Islands of Global Settlements Using MODIS and Nighttime
Lights Products**

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Prepared for the

Canadian Journal of Remote Sensing, Special Issue: Urban Remote Sensing

Abstract

Impervious surface area (ISA) from the National Geophysical Data Center (NGDC) and land surface temperature (LST) from MODIS averaged over three annual cycles (2003-2005) are used in a spatial analysis to assess the urban heat island (UHI) signature on LST amplitude and its relationship to development intensity, size, and ecological setting for more than 3000 urban settlements over the globe. Development intensity zones based on fractional ISA are defined for each urban area emanating outward from the urban core to the nearby non-urban rural areas and used to stratify sampling for LST. Sampling is further constrained by biome type and elevation data to insure objective inter-comparisons between zones and between cities in different biomes.

We find that the ecological context and settlement size significantly influence the amplitude of summer daytime UHI. Globally, an average of 3.8 °C UHI is found in cities built in biomes dominated by forests; 1.9 °C UHI in cities embedded in grass/shrub biomes; and only a weak UHI or sometimes an Urban Heat Sink (UHS) in cities in arid and semi-arid biomes. Overall, the amplitude of the UHI is negatively correlated ($R = -0.66$) to the difference in vegetation density between urban and rural zones represented by MODIS Normalized Difference Vegetation Index (NDVI). Globally averaged, the daytime UHI amplitude for all settlement is 2.6 °C in summer and 1.4 °C in winter. Globally, the average summer daytime UHI is 4.7 °C for settlements larger than 500 km², compared to 2.5 °C for settlements smaller than 50 km² and larger than 10 km². The stratification of cities by size indicates that the aggregated amount of ISA is the primary driver of UHI amplitude with variations between ecological contexts and latitudinal zones. More than 60% of the total LST variances is explained by ISA for urban settlements within forests at mid-to-high latitudes. This percentage will increase to more than 80% when only USA settlements are examined.