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# The impact of urbanization and the urban heat island effect on day to day temperature variation

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ABSTRACT

Day to day temperature variation of daily temperature minimum ($T_{min}$) and temperature maximum ($T_{max}$) were examined for five urban–rural pairs of climate stations in North America. Day to day temperature variation was measured by averaging the absolute difference between one day and the previous day for a given time period (e.g., month). For rural sites, day to day temperature variation was typically greater for $T_{min}$ than $T_{max}$. The opposite was found for urban locations, with statistically significant stronger signals for larger cities. It is proposed that the difference of these measures (day to day $T_{max}$ variability less day to day $T_{min}$ variability) can be used to distinguish between rural and urban stations and as a measure of increasing urbanization. Also, it is suggested that the magnitude of total change in day to day temperature variability (ΔDTD) can be used to decide a suitable urban/rural pair for any urbanization impact study.



## 1. Introduction

The urban heat island (UHI), an anthropogenically generated phenomenon, is a distinct surface signature of human habitation. The UHI occurs when an urban center is warmer than its surrounding

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environs. This effect may be up to 10 °C warmer, although there is considerable variation due to different local environments and atmospheric conditions.

The extent of the built environment, population size and density, anthropogenic activity, and socio-economic aspects of a city play a critical role in determining the effect of urbanization on temperature variation (Chen et al., 2006; Oke, 1978). The UHI is most readily detected at night and in the winter months. However, the magnitude of the UHI differs from city to city due to different local physiographical features and climate characteristics. The UHI is more distinct when regional/local winds are weak or non-existent, while the UHI effect may be obscured by the mitigating effects of land/lake breezes. Influences of the UHI include (but not limited to) a reduction of evaporation and evapotranspiration due to paved surfaces and reduced vegetation; lower albedo (reflectivity) due to the built environment and/or snow removal; daytime heating of urban surfaces; the generation of heat from local infrastructure (e.g., industry, commercial, and residential buildings, and transportation vehicles/systems), and excess heat trapped by urban pollution, notably aerosols (Oke, 1978).

A combination of these factors alters the exchange of incoming and outgoing solar radiation affecting the radiative balance; influencing a rise in local temperatures. This balance begins with incoming solar radiant energy that is partitioned at the surface to either heating the surface and subsurface or evaporating moisture. Heating the surface increases surface temperature; whereas evaporating moisture partitions the energy into latent heat that does not directly heat the surface. In typical urban environments, more energy goes into surface heating and less into evaporation, thus increasing heat storage and surface temperature. Moreover, tall buildings create a complex geometry that traps energy and alters airflow, increasing the amount of energy available to heat the urban surface. Heat storage and surface heating in rural areas, on the other hand, are mitigated by the cooling effect of larger areal coverage of green spaces and typically greater abundance of water surfaces.

There are various approaches in detecting an UHI; common methods include the use of climate data, satellite imagery, or mathematical modeling that compare a climate variable or indicator between two locations (Gough and Rosanov, 2001; Huang et al., 2008; Mohsin and Gough, 2010; Oke, 1978; Weng, 2003; Yague and Zurita, 1991). Such analyses tend to be complex and at times, may require sophisticated analysis and readily available data. In this work, we present an alternate innovative approach in detecting the magnitude of an urban footprint that is, in contrast, clear, straight-forward and readily applicable.

## 2. Methods

### 2.1. Theory

In this work, day to day temperature variation was compared between urban and rural climate stations using a novel metric that requires daily temperature minimum ($T_{\min}$) and temperature maximum ($T_{\max}$) data. Day to day temperature variation is used as the climate measure to assess differences in urban–rural pairs based on a conceptual understanding of how energy is partitioned differentially in urban and rural settings in temperate climate locations.

To provide a brief framework for the subsequent analysis, we briefly consider the anticipated impacts of urbanization on day to day temperature variation. As already established, urban areas tend to be warmer than their surrounding environs. This is due to differences in surface environments (e.g., built versus natural) between urban and rural areas, which result in differences in the overall albedo and emissivity of the local area (Jin et al., 2005). The albedo and emissivity of urban areas tend to be approximately 5% and 3% (respectively) lower than that of adjacent croplands (Jin et al., 2005). A combination of lower albedos and different surfaces (i.e., asphalt versus forests) results in greater internal storages of sensible heat in the urban environment; as such, radiative partitioning differs between urban and rural areas. Maximum temperature typically occurs during the day in mid afternoon. In an urban setting, incoming solar radiation is mainly partitioned into sensible heat, subsurface heating and, to a lesser extent, latent heat (evaporation of surface water). This can lead to a substantial increase of temperature for a given radiative input. The rural setting with the same radiative input partitions considerably more into latent heating (assuming in general a greater availability of surface