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Application of spatially gridded temperature and land cover data sets for urban heat island analysis

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ABSTRACT

Two gridded data sets that included (1) daily mean temperatures from 2006 through 2011 and (2) satellite-derived impervious surface area, were combined for a spatial analysis of the urban heat-island effect within the Dallas-Ft. Worth Texas region. The primary advantage of using these combined datasets included the capability to designate each 1 × 1 km grid cell of available temperature data as urban or rural based on the level of impervious surface area within the grid cell. Generally, the observed differences in urban and rural temperature increased as the impervious surface area thresholds used to define an urban grid cell were increased. This result, however, was also dependent on the size of the sample area included in the analysis. As the spatial extent of the sample area increased and included a greater number of rural defined grid cells, the observed urban and rural differences in temperature also increased. A cursory comparison of the spatially gridded temperature observations with observations from climate stations suggest that the number and location of stations included in an urban heat island analysis requires consideration to assure representative samples of each (urban and rural) environment are included in the analysis.

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1. Introduction

The percentage of the global population located in urban areas increased from less than 30% in 1950 to over 50% in 2011 (United Nations, 2012). By 2030 60% of the global population is estimated to reside in an urban environment (United Nations, 2012). Thus, the assessment and monitoring of urban environments will only increase as does the inhabitants of these locals.

The differences observed in meteorological variables between urban and rural environments have been the subject of considerable research (e.g., Arnfield, 2003). These differences, commonly referred to as the urban heat island (UHI) effect are often characterized through comparisons of data from weather/climate stations designated as either urban or rural (Stone, 2007). Other comparisons include observed meteorological station data and data provided from reanalysis efforts (Kalnay and Cai, 2003). These comparisons rely on the expectation that the reanalysis data are not affected by meteorological station observations (that may be influenced by the UHI effect) and thus differences in the observed and reanalysis data can provide an indication of the UHI effect over time.

Within previous UHI studies, observation stations have been generally characterized as urban or rural based on population of nearby cities (Peterson and Vose, 1997), population at the station location estimated from gridded population data (Owen and Gallo, 2000), level of nighttime light at the location of the stations (Owen et al., 1998; Hansen et al., 2001), and combinations of gridded nighttime light and land cover datasets (Gallo and Owen, 2002). Hausfather et al. (2013) characterized stations as urban or rural based on an impervious surface dataset that combined gridded nighttime light and population data (Elvidge et al., 2007).

Impervious surface area (ISA) represents a physical characteristic of the land surface that is correlated with the amount of urban-related features (e.g., asphalt, concrete, rooftops) within the observed area or grid cell (Arnold and Gibbons, 1996). Fractional ISA has been used to characterize urban land cover features (Xian et al., 2007) and combined with gridded satellite data (land surface temperature) to determine spatial features of an UHI (Xian and Crane, 2006). The availability of datasets that include spatially continuous characterization of the land use/land cover and associated characteristics including ISA (Homer et al., 2007) and spatially continuous meteorological data sets (e.g., Daymet; Thornton et al., 2012) afford a unique opportunity to spatially assess the UHI effect beyond the limited locations of traditional climate or meteorological observation stations. Additionally, these gridded data sets could be used to compliment other gridded data (e.g., satellite derived data) utilized in previous studies of UHIs (e.g., Chen et al., 2006; Gallo et al., 1993, 2004; Jin, 2012; Weng, 2009; Xian and Crane, 2006).

The objective of this study was to evaluate the use of spatially gridded temperature data combined with a gridded data set useful for identifying levels of urban-related characteristics (e.g., percent cover of impervious surface area (ISA) in a grid cell), within an analysis of the temperature differences between urban and rural (non-urban) locations. This study examines the temperature differences between the urban and rural locations for several levels of urbanization as defined by the level of ISA. This initial assessment includes the Dallas-Ft. Worth, Texas region.

2. Methods

2.1. Impervious surface area data

While several impervious surface area (ISA) datasets are available (e.g., Elvidge et al., 2007) the ISA used in this analysis was derived from the 2006 National Land Cover Database (Homer et al., 2007; Xian et al., 2011) defined at 30 m. Development of the NLCD 2006 ISA data set utilized Landsat 30 m reflectance and 90 m thermal data as well as nighttime light data (to assist with urban boundary definition) and other ancillary data described in Xian et al. (2011). The original 30 m ISA was degraded to 1 km to match the spatial resolution of the gridded climate data. The ISA was used to define each 1×1 km grid cell as either urban or rural based on the level of ISA within each grid cell. Three ISA levels were used in this study and included ISA levels of $\geqslant$5% (ISA5), 25% (ISA25), and 50% ISA (ISA50). These ISA levels were used in this study as thresholds to define the 1×1 km grid cells as