RECENT PROGRESS IN THERMAL REMOTE SENSING OF URBAN AREAS

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Remotely sensed imagery has been increasingly used to study the urban heat island phenomenon by deriving and analyzing land surface temperatures. The technology of remote sensing has the advantage of providing a time-synchronized dense grid of temperature data over a whole city region and distinctive temperature measurements for individual buildings. Moreover, some remote sensing images have high temporal resolution, in addition to being cost-effective. A key issue in the application of remote sensing technology is how to use land surface temperature measurements at the micro-scale to characterize, quantify, and model heat islands observed at the meso-scale. The findings reported here are from our funded project by U.S. National Science Foundation, which is entitled "Role of urban canopy composition and structure in determining heat islands: a synthesis of remote sensing and landscape ecology approach". The project aimed at examining the effect of urban surface composition and structure on urban surface energy budgets and a better understanding of the thermal behavior of urban landscapes and the heat island phenomena, and was conducted in Indianapolis, Indiana, United States, with satellite images from sensors of various spatial, spectral, and temporal resolutions, including Landsat TM, ETM+, Terra's ASTER, and MODIS thermal infrared data. Specifically, there were three objectives: (1) To investigate the relationship between land surface temperature (LST) and quantitative surface biophysical descriptors, which are sub-pixel measurements, derived from spectral unmixing of medium-resolution satellite images; (2) To examine the scaling-up effect on the relationship between land use and land cover (LULC) and LST patterns by the use of landscape metrics; and (3) To relate micro-scale (pixel) measurements of LST to meso-scale UHI measurements of the entire city, in order to derive UHI parameters: magnitude, the spatial extent, the orientation, and the central location.

To meet Objective 1, an analytical procedure was developed for characterizing and quantifying the urban landscape in Indianapolis based on linear spectral mixture analysis (LSMA). A Landsat

Enhanced Thematic Mapper Plus image of the study area, acquired on June 22, 2002, was spectrally unmixed into four fraction endmembers, namely green vegetation, soil, high and low albedo. Impervious surface was then computed from the high and low albedo images. A hybrid classification procedure was developed to classify the fraction images into seven land use and land cover classes. Next, pixel-based LST measurements were related to urban surface biophysical descriptors derived from LSMA. Correlation analyses were conducted to investigate land cover based relationships between LST and impervious surface and green vegetation fractions. An examination of LST variations within census block groups and their relationships with the compositions of LULC types, sub-pixel biophysical descriptors, and other relevant spatial data shows that LST possessed a weaker relation with the LULC compositions than with other variables, including urban biophysical descriptors, remote sensing biophysical variables, GIS-based impervious surface variables, and population density (Weng et al. 2006).

The scaling-up effect on the spatial and ecological characteristics of landscape patterns and LSTs were examined by the use of landscape metrics, which inluded Patch Density, Landscape Shape Index, Perimeter- area Fractal Dimension, Mean Perimeter-area Ratio, Proximity Index, and Contagion Index. Four Terra's ASTER images were acquired to derive the land use and land cover (LULC) patterns and land surface temperatures (LST) in different seasons. Each LULC and LST image was resampled to eight spatial scales, i.e., 15, 30, 60, 90, 120, 250, 500, and 1000 m. Each metric represented one dimension in the space. Optimal scale was determined based on the minimum distance in the landscape metric spaces. Figure 1 shows the Eculidean distance as a function of spatial resolution at the four imaging dates. Around 90 meter was found to be the optimal spatial scale for assessing the landscape-level relationship between LULC and LST (Liu and Weng, 2009). Further studies are needed to investigate the impacts of the following factors on the computation of the Eculidean distance. These factors include the quality of remote sensing data, acquisition time, pixel aggregation methods, and the sensitivity of individual landscape metric.

In order to use LST measurements to characterize and quantify UHIs observed at the meso-scale and to derive the UHI parameters, Rajasekar and Weng (2009) applied a non-parametric model by using fast Fourier transformation (FFT) to MODIS imagery for characterization of the UHI over space, so that UHI magnitude and other parameters may be derived. Figure 2 shows selected models of the daytime UHIs characterized from the MODIS LST images of 2006 in Indianapolis.

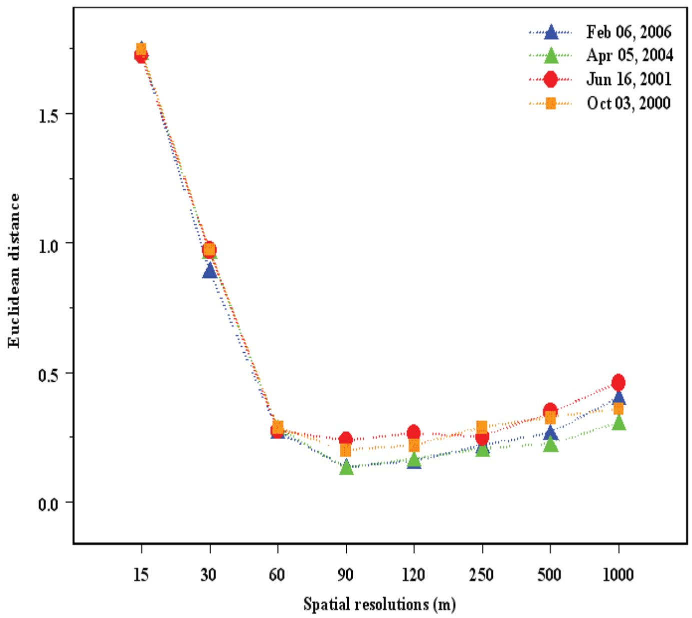

Figure 1. Optimal spatial scale for assessing the landscape-level relationship between LULC and LST based on the minimum distance in the landscape metric space

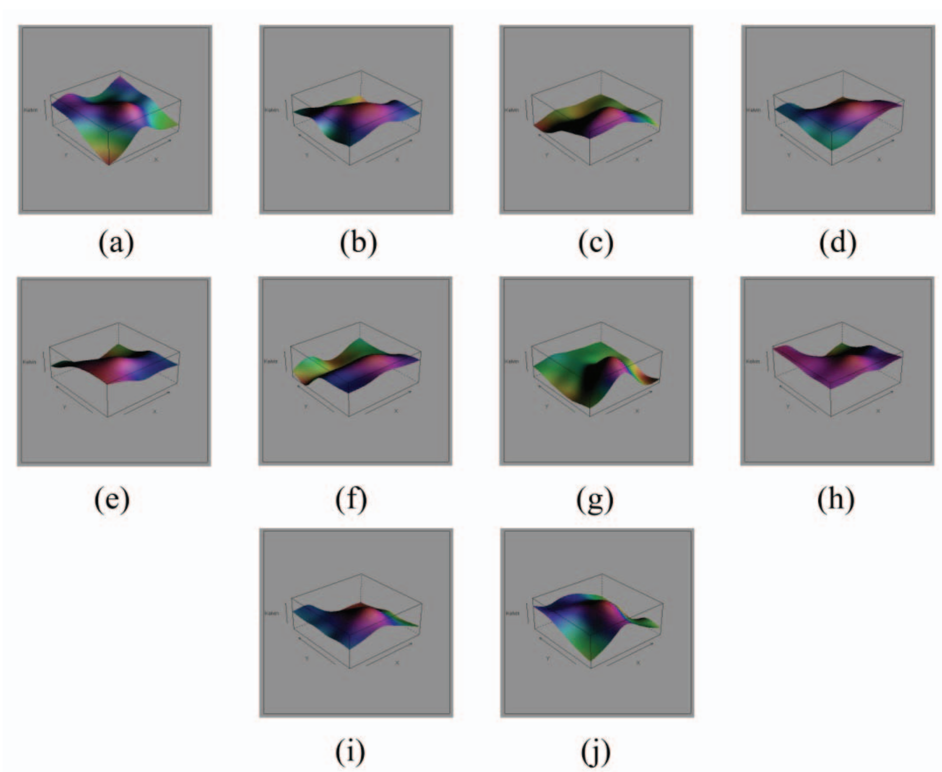

Figure 2. Selected models of the daytime UHIs characterized from the MODIS LST images of 2006 in Indianapolis, United States. The models from (a) to (j) are derived from the following dates of images:

February 18, March 15, April 14, May 24, June 24, July 9, August 21, September 30, October 4, and November 11. (Source: Rajasekar and Weng, 2009)

CONCLUSIONS

This project synthesized optical remote sensing of urban construction materials and the composition, thermal remote sensing of land surface temperatures, and the landscape ecology approach. Through use of physical modeling, statistical analysis, and fractal geometry, a protocol has been established to study the interactions among urban surface characteristics, the thermal behavior of urban landscapes, and urban heat islands. In spite of the advances illustrated in this research, estimation of UHI parameters from multi-temporal and multi-location TIR imagery is still a promising research direction in the future given the increased interest from urban climate/environment community to use remote sensing data.

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