Downscaling MODIS Land Surface Temperature for Urban Public Health Applications

Authors: Mohammad Al-Hamdan*, William Crosson¹, Maurice Estes, Jr.¹, Sue Estes¹, Dale Quattrochi², Daniel Johnson³

¹University of Arizona, Tucson, AZ, USA
²University of North Carolina at Chapel Hill, Chapel Hill, NC, USA
³Indiana University and Purdue University in Indianapolis, Indiana, USA

1. Overview

This study is part of a project funded by the NASA Applied Sciences Public Health Program, which focuses on Earth science applications of remote sensing data for enhancing public health decision-making. Heat-related death is currently the number one weather-related killer in the United States. Mortality from these events is expected to increase as a function of climate change. This activity sought to augment current Heat Watch/Warning Systems (HWWS) with a remotely sensed dataset, and models used in conjunction with sociodemographic and heat-related mortality data. The current HWWS does not take into account intra-urban spatial variations in risk assessment. The purpose of this effort is to evaluate potential methods to improve spatial delineation of risk from extreme heat events in urban environments by integrating sociodemographic risk factors with land surface temperature (LST) estimates derived from thermal remote sensing data. In order to further improve the assessment of intra-urban variations in risk from extreme heat, we developed and evaluated a number of spatial statistical techniques for downscaling the 1-km daily MODerate resolution Imaging Spectroradiometer (MODIS) LST data to 60 m using Landsat-derived LST data, which have finer spatial but coarser temporal resolution than MODIS. These techniques have been demonstrated and validated for Phoenix, AZ; Philadelphia, PA; and Dayton, OH using data from the summers of 2006-2006.

2. Goals-Objectives and Motivation

This overall goal of this project, which this study is part of, is to augment current Heat Watch/Warning Systems (HWWS) with a remotely sensed dataset, and models used in conjunction with sociodemographic and heat-related mortality data. The objectives of this study is to develop and evaluate a number of spatial statistical techniques for downscaling the 1-km daily MODIS LST data to 60 m using Landsat-derived LST data, which have finer spatial but coarser temporal resolution than MODIS. This will improve the assessment of intra-urban variations in risk from extreme heat, which is something that current HWWS do not take into account.

3. Study Areas

Phoenix, AZ
Philadelphia, PA
Dayton, OH

4. Methods Development and Applications

A. Deriving LST from Landsat thermal data

We followed the Weng et al. (2004)* procedure to derive land surface temperature (LST) from Landsat thermal data, which involves three steps:

1. Converting the digital number of Landsat TM or ETM+ TIR band into spectral radiance
   
   \[ \text{Radiance} = 0.0370588 \times \text{DN} + 3.20 \]  
   (For Landsat TM)
   
   \[ \text{Radiance} = 0.0553760 \times \text{DN} + 1.18 \]  
   (For Landsat ETM+)

2. Converting the spectral radiance to at satellite brightness temperature (i.e., blackbody temperature, \( T_b \))
   
   \[ T_b = \frac{k}{\ln(1 + \frac{\text{Radiance}}{T_b})} \]

Where \( k \) = Planck's constant (6.626 \times 10^{-34} \text{ J s}), \( \lambda \) = wavelength of emitted radiance (\( \lambda = 11.5 \text{ um} \)), \( \rho \) = h/\( c \), \( h \) = Planck's constant (6.626 \times 10^{-34} \text{ J s}), and \( c \) = velocity of light (2.998 \times 10^8 \text{ m/s}).

3. Converting the blackbody temperature to land surface temperature (LST) which involves correcting for spectral emissivity according to the nature of the land cover. We identified the land cover land use (LCLU) classes using the Landt-derived NLCD-2001 data. Each of the LCLU classes was assigned an emissivity value by reference to the emissivity classification scheme by Snyder et al. (1998)**

\[ \text{LST} = T_b \left( 1 + \frac{\lambda}{T_b} \right) / \rho \]

Where: \( k \) = wavelength of emitted radiance (\( \lambda = 11.5 \text{ um} \)), \( p = \text{h/}c \), \( \rho = 1.438 \times 10^{-2} \text{ m K}^{-1} \text{sr}^{-1} \text{W}^{-1} \), \( K = \text{Boltzmann constant} (\text{1.38} \times 10^{-23} \text{ J K}^{-1}) \), \( h = \text{Planck's constant} (6.626 \times 10^{-34} \text{ J s}) \), and \( c = \text{velocity of light} (2.998 \times 10^8 \text{ m/s}) \).

B. Downscaling MODIS LST

1. Differences Method (illustrated for Phoenix, AZ)

\[ \Delta T_b = \left( \frac{\text{LST}_{\text{Landsat}} - \text{LST}_{\text{MODIS}}}{{\Delta}_{\text{MODIS}}} \right)^{0.5} \]

2. Ratios Method (illustrated for Phoenix, AZ)

\[ \frac{\text{LST}_{\text{MODIS}} \times R_{60m}}{\text{LST}_{\text{MODIS}}} = \text{LST}_{\text{60m}} \]

C. Statistical Normalization Method (illustrated for Phoenix, AZ)

\[ \Delta T_b = \left( \frac{\text{LST}_{\text{Landsat}} - \text{LST}_{\text{MODIS}}}{{\Delta}_{\text{MODIS}}} \right)^{0.5} \]

Adjustment Factor Development

Model Application/Validation

Application of Differences Method for Phoenix, AZ on August 28, 2004

Application of Ratios Method for Phoenix, AZ on August 28, 2004

Application of Statistical Normalization Method for Phoenix, AZ on August 28, 2004

6. Summary

In this project, we developed and evaluated a number of spatial statistical techniques for downscaling the 1-km daily MODIS LST data to 60 m using Landsat-derived LST data, which have finer spatial but coarser temporal resolution than MODIS. This will improve the assessment of intra-urban variations in risk from extreme heat, which is something that current HWWS do not take into account. Three methods were first developed and validated for Phoenix, AZ, among which the Statistical Normalization Method showed the lowest errors, followed by the Ratios Method and the Differences Method that had the highest errors. Thus, the Statistical Normalization Method was applied and validated for other datasets/cities. Validation results from two different dates for Phoenix, AZ were generally similar to each other, which is a positive sign for the model’s robustness. Results from Dayton, OH were also generally similar to those from Phoenix, AZ. However, results from the Statistical Normalization Method application and validation for Philadelphia, PA showed higher errors than the other two cities, which could be due to the fact that there are lots of water bodies within the urban area, maximizing the mixed pixel effect and increasing the discrepancy between the MODIS and Landsat LST estimates.

*For sharper rendering, a two-domain downscaling method was applied and evaluated for Phoenix, AZ on August 28, 2004.

Additional support for this study was provided by the NASA Applied Sciences Program. The authors would also like to thank them.

American Geophysical Union Fall Meeting
San Francisco, CA, December 13, 2013

https://ntrs.nasa.gov/search.jsp?R=20140006517 2020-04-02T11:57:33+00:00Z