**Snyder, W. C., Wan, Z., Zhang, Y., & Weng using data from the summers of 2000.**

Techniques have been demonstrated and validated for Phoenix, AZ; Philadelphia, PA; and Dayton, GA in 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 improve spatial delineation of risk from extreme heat events in urban environments. Mortality from these events is expected to increase as a function of climate change. 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, GA using data from the summers of 2000-2006.

**2. Goals-Objectives and Motivation**

This overall goal of this project, which is part of, is to augment current Heat Watch/Warning Systems (HWWS) with NASA remotely sensed data, and models used in conjunction with socioeconomic 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
   
   \[ \text{Radiance} = 0.0370588 \times \text{DN} + 3.20 \]  
   \[ \text{(For Landsat 7 ETM+)} \]

   \[ \text{Radiance} = 0.0553760 \times \text{DN} + 1.18 \]  
   \[ \text{(For Landsat TM)} \]

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

3. Converting the blackbody temperature to land surface temperature (LST) which involves correcting for spectral emissivity according to the nature of land cover. We identified the land cover land use (LCLU) with the National Land Cover Data (NLCD 2001) for both Phoenix and Dayton. Each of the LCLU classes was assigned an emissivity value by reference to the emissivity classification scheme by Snyder et al. (1998)**. The emissivity corrected LST was computed as follows (Artis & Carnahan, 1982):**
   
   \[ LST = T_b \left[1 + \left( \frac{\text{Radiance}}{T_b} \right) \times \ln(\varepsilon)\right] \]

   Where, \( k \) is the wavelength of emitted radiation (\( \lambda = 11.5 \mu \text{m} \)), \( p = h \times c / (2 \times 10^5 \mu \text{m} \times k, \) and \( \varepsilon = \text{Boltzmann constant} \) (3.8 x 10^-22 J/K), \( h = \text{Planck’s constant} \) (6.626 x 10^-34 J s), and \( c = \text{velocity of light} \) (2.998 x 10^8 m/s).

**B. Downscaling MODIS LST**

**1. Differences Method (illustrated for Phoenix, AZ)**

\[ \text{MODIS}_{1km} - \text{MODIS}_{60m} = \Delta_{60m} \]

**2. Ratios Method (illustrated for Phoenix, AZ)**

\[ \text{MODIS}_{1km} \times R_{60m} = \text{MODIS}_{60m} \]

**3. Statistical Normalization Method (illustrated for Phoenix, AZ)**

**5. Methods Validation**

**1. Differences Method (illustrated for Phoenix, AZ)**

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

**2. Ratios Method (illustrated for Phoenix, AZ)**

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

**3. Statistical Normalization Method (illustrated for Phoenix, AZ)**

Validation 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 dates/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 estimations.

For sharper rendering, a two-standard deviation sketch was applied for all the raster maps mapped in sections 4C.