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Community Exposure to Nighttime Heat in a Desert Urban Setting, El Paso, Texas

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Abstract The combination of global warming and urbanization is expected to exacerbate the well-established urban heat island effect. Unfortunately, little is known about nighttime urban heat retention and its possible health effects on residents. Here we use infrared satellite imagery to evaluate the distribution of nighttime heat and its decadal changes in a large desert metroplex.
Keywords *Human Health, Nighttime Heat; Heat Exposure; Global Warming; Desert Cities; Thermal Infrared (IR) Satellite Imagery; Community Risk; Urban Growth; Urban Heat Island; Change Detection*

1. Background – The Urban Heat Island

The urban heat island was first described in London by Howard nearly two centuries ago [1]. The importance of this phenomenon has increased with the acceleration of urbanization, first in the industrialized world and, since the Second World War, through much of the remainder of the globe. Population growth has been a key driver of urbanization. Such growth also drives global warming, a more recent and increasing contributor to urban heat [2]. Unplanned and unregulated urban growth alters such thermal regulators as albedo, and the roughness and heat capacities of the urban surface [3].

In general, the temperature contrast between the urban heat island and the surrounding region is greater at night than during the day [4], [5]. This results from such factors as heat capacity of the materials in the two compartments and decreases in air convection during the night. However, this relationship might not be as strong in sparsely vegetated arid or desert regions, or at higher elevations where heat convection is more effective.

2. Study Area – El Paso, Texas, USA

Post-World War II urbanization in El Paso, Texas, USA and in its contiguous (separated only by the

Rio Grande) sister city of Ciudad Juarez, Chihuahua, Mexico has created a bi-national urban metroplex with an estimated 2 million inhabitants (Figure 1). The region lies in the Chihuahuan desert, characterized by temperatures of 35-40^{o} C in summer, high elevation of 600-1675 m, and annual rainfall of less than 250 mm.

We employed infrared band satellite imaging to establish the variation of nighttime neighborhood surface temperatures across the city of El Paso, as well as all of El Paso County [6]. Data were retrieved for the summer months of June, July, and August, which encompass the highest temperature regime in the annual cycle.

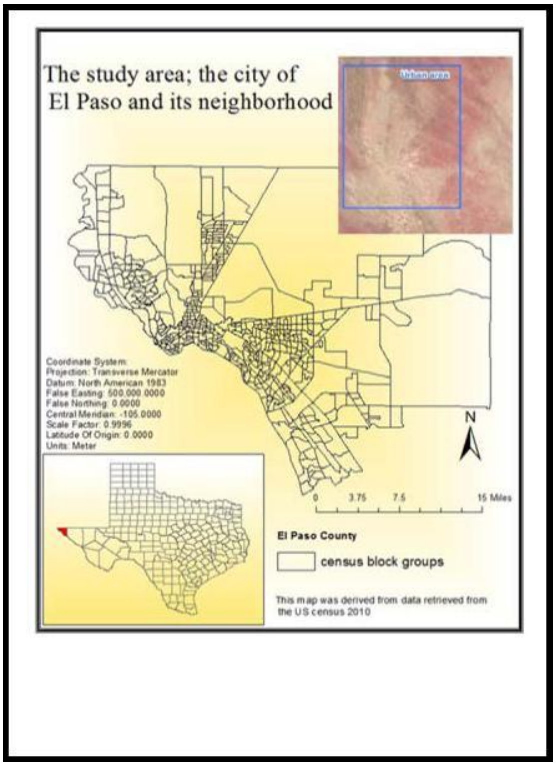

Figure 1: *El Paso City and County, Far West Texas USA*

3. Goal – Geography of Risk

Our continuing investigation asks a fundamental question: *do different neighborhoods pose different risks of exposure to high nighttime temperatures?* Posed more formally, we seek to define the geospatial distribution of morbidity risk consequent to elevated nighttime temperatures [7], [8]. The health risks associated with elevated temperature are well established, and can include heat stress, irritability, exacerbation of pre-existing medical conditions, and sleep deprivation, with possible resultant violence [9-11]. Exposure to heat at night is especially important because residents typically are in the home during these hours. Furthermore, some 90% of El Paso residents depend on evaporative or “swamp” coolers rather than the more effective conventional “refrigerated” air conditioning. Although evaporative coolers are much less expensive both to purchase and to operate, they raise the humidity of only partly cooled air and thus are less effective in cooling residents. Furthermore, their cooling ability falls sharply during El Paso’s late summer high-humidity “monsoon” period.

4. Procedures – Remote Imagery and Processing

Source materials for our study included: Advanced Spaceborne Thermal Emission and Reflection Radiometer), ASTER Global Digital Elevation Model V002, Landsat 7 Enhanced Thematic Mapper Plus, and Landsat 5 Thematic Mapper. From these we extracted and calculated Land Surface Temperature (LST); Land Surface Albedo (LSA), several Land Use Land Cover (LULC) classes, and the Normalized Difference Vegetation Index (NDVI). Processing packages included ArcMap version 10.1 and Environment for Visualizing Images (ENVI) version 5.0. Geographically Weighted Regression version 4.0. explored spatial relationships between LST and LSA, NDVI, elevation, and population density. We delineated the geographic distribution of social vulnerability relative to the LST via six social and biophysical indicators: total population, income, poverty, age over 65, LST, and NDVI.

5. Findings

The geographically weighted regression model revealed that day and nighttime land surface temperatures both were correlated with the normalized difference vegetation index, population density, and albedo. The index and albedo associations were stronger with daytime temperature and the population density association was stronger with nighttime temperature. Vegetation (negative) and population density (positive) were the strongest associations with temperature, followed by albedo and elevation.

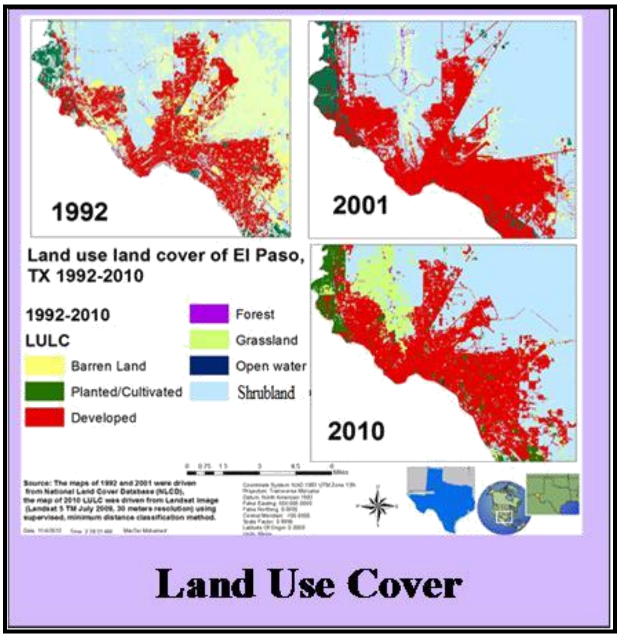

Figure 2: *Decadal Sequence of Land Use in El Paso County*

Large difference in land use over the past two decades reflects increasing urbanization (Figure 2). Development, indicated in red on the maps, is the key driver of the urban heat island effect.

Archived satellite imagery (Figure 3) indicated increases in both day and nighttime temperatures over the last two decades. With no expected change in urban growth and global warming, local residents will be at increasing risk in the future, as will residents in other urban centers in the desert southwest of the US.

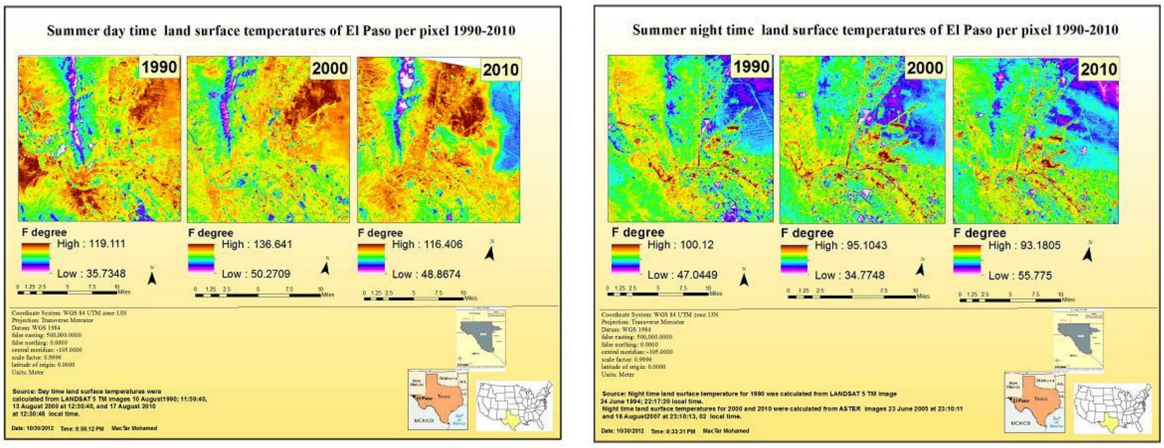

Figure 3: *Decadal Sequence of Summer Day (Left) and Night (Right) Land Surface Temperatures in El Paso County*

6. Public and Societal Health Implications

Socio-economic status, groups of people with the same income, power, and prestige, can be a powerful contributor to social vulnerability. Those of a lower socio-economic status tend to live in the poorer areas in low quality and often older housing with few resources available for heat mitigation [12]-[14]. Several studies have demonstrated higher heat-related mortality among people living in poor neighborhoods within cities [15], [16]. Here *we combined the geographies of physical environmental and socio-economic data to create a nighttime and daytime vulnerability heat index (NVHI & DVHI)* based on population density, income, % population below poverty level, population over 65 years, LST, and NDVI (Figure 4). It should be noted that the median El Paso income (2010) was $37,152, with 25% of residents living below the national poverty line. Poverty in El Paso by and large follows population density.

In general, the proximal or urban core central, northeast, and eastside of the study area tend toward high vulnerability while the westside tends toward low vulnerability. This agrees with population density and economic status. This pattern is best seen in the “hot spot” maps (Figure 5). Also, there was a trend toward a shift in vulnerability from surrounding rural areas to the urban area between 2000 and 2010.

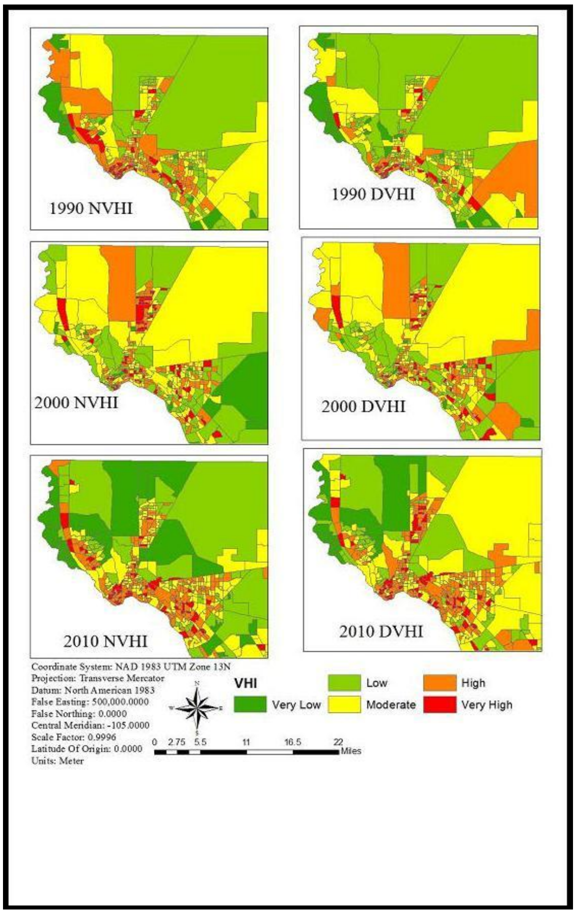

Figure 4: *Decadal Sequence of Derived "Socio-Thermal" Nighttime and Daytime Vulnerability Heat Index*

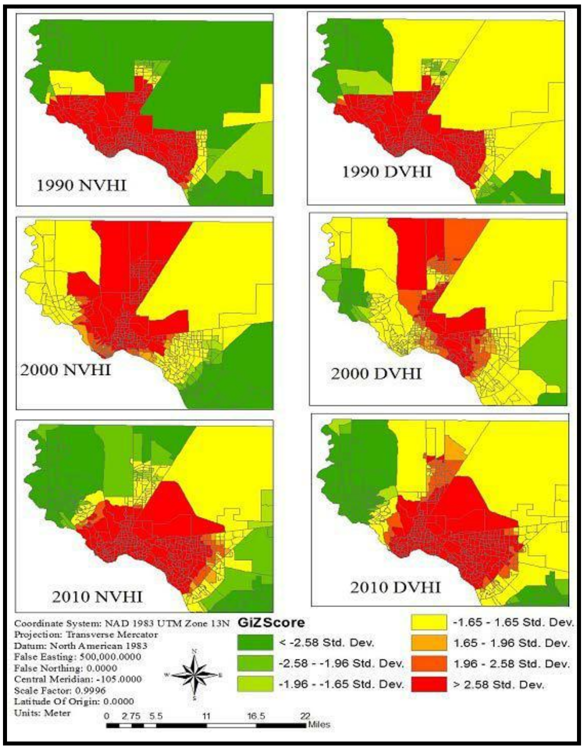

Figure 5: *Decadal Sequence of El Paso County Heat Vulnerability "Hot Spots"*

7. Mitigation Strategies

By 2060, the total population of El Paso County is projected to reach 1.5 million residents [17]. The overall pattern of our maps and global warming trends suggest that exposure and vulnerability to heat will continue to increase in this urban region in the near future. On a more positive note, the maps delineate the neighborhoods most likely to require heat prevention and intervention strategies because of both the ambient heat load and the special vulnerabilities of their residents (NVHI).

An obvious and relatively simple economic and political approach to slowing, stopping, or even reversing the trend toward higher nighttime temperatures in vulnerable neighborhoods is to increase greenspace in these critical areas. Such a program, carried out with the cooperation of the community could include streetside planting of native (xerophytic) trees and bushes; addition of park space, particularly numerous dispersed "pocket parks;" tax or other incentives for businesses to add native trees and bushes to their parking lots; similar programs for unoccupied private real estate lots; and so forth.

More intense immediate strategies could include educational and in-house servicing programs to ensure proper functioning of pre-existing evaporative cooling systems, assistance in purchasing and installing additional evaporative coolers, circulating fans, and window tinting. Longer-term strategies would include integration of heat vulnerability into local public-housing programs and medical assistance programs.

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