Instruction: proposal to class project

(Hongjie Xie, 10/20/2008)

A project proposal is the first step to us to get funding from anywhere. You need to write a proposal to your advisor, your university, your company, your city, state, governmental agencies (USGS, USDA, NSF, NASA, NOAA, DoEd, DOE, ….) for any funding opportunity. A proposal for a small amount of fund is usually 5 pages; for a standard and multi-year proposal to governmental agencies, it is usually 15 pages. The format for a proposal might change from agency to agency, from announcement to announcement, or from program to program, but several basic elements should be included: (1) a introduction to state the current problems and why you want to propose this project; (2) objectives and significant of the project and hypotheses or questions you want to answer; (3) what kind of data, method and modeling approach you will use to conduct the project, and usually you need to show some preliminary or previous results; (4) expected results after you finished the project; and (5) relevant to the research announcement. See an example proposal I just submitted to UTSA for a small amount of fund, which is five pages and includes all the elements that I listed above.

For the class project (or a review a paper or a topic of several papers), you are required to submit a proposal of at least one page (single space) include most of the elements above (may be not the element 5), but with a rather short version. If you are interested in working on the proposed urban heat island project, you are welcomed to do so for only one city, instead four cities.

Some students have already discussed with me about their projects, but some have not yet. I encourage you come to talk to me in this week and next week and I will help you (maximum 2 as a group) to setup your project.

Remote sensing urban heat-island phenomenon in four Texas cities: San Antonio, Houston, Dallas-Fort Worth, and El Paso

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1. Introduction

The temperature of an urban area is often higher than the surrounding rural areas. It looks like a hot island standing out in a sea of relative cool areas. This phenomenon is called urban heat island (UHI) effect, an anthropogenically induced climate feature associated with the contrast surface characteristics between urban and rural areas [*Sturman and Tapper*, 2006]. The use of heat-absorbing construction materials (stone, metal, asphalt and concrete) for building roads, driveways, sidewalks, parking lots, and rooftops, the impermeable surfaces (road surface, parking lot, rooftops) based on those materials, the reducing vegetation covered area, and artificial heat release (cars and air conditioners) are the major reasons for UHI. It is common to find cities that heat island intensity (the difference between the urbanized city and its rural surroundings) is as high as 10 degrees. The increased temperature not only leads to adverse climate, but also drives up energy use for air conditioning and the pollution level. Thus, it is critical to include UHI effects in any urban development of the future [*Collier*, 2006].

Figure 1. The temperature profile (orange) indicating higher temperatures over a city's downtown area.

There are three types of UHI: canopy layer heat island (CLHI), boundary layer (~1 km above the canopy layer) heat island (BLHI) and land surface heat island (LSHI) (Voogt, 2004). The CLHI and BLHI refer to a warming of the urban atmosphere; the LSHI refers to a warming of the urban land surface. Scientists measure air temperatures for CLHI or BLHI directly using thermometers. Over the past decade, however, remotely sensed imagery has been increasingly used to study LSHI by computing land surface temperatures from these images. The technology of remote sensing has the advantage of providing a time-synchronized dense grid of temperature data over a whole city and distinctive temperatures for individual buildings, parking lots, and vegetative area, and is thus cost-effective. In the proposed TRAC study, we will use remote sensing technology to study the LSHI (i.e. UHI for simplification, therefore in the proposal).

Vegetation coverage in urban areas is believed to effectively reduce UHI [*Wilby and Perry*, 2006]. It is also found that microclimate in urban environments influences plant physiological activities [*Mueller and Day*, 2005]. Thus, it is important to find an appropriate vegetation distribution structure to optimize its environmental function (including UHI mitigation) in urban areas. Although a few studies have been conducted to quantitatively characterize the effects of vegetation coverage in the urban area on UHI e.g. [*Hien et al.*, 2007; *Hirano et al.*, 2004; *Weng et al.*, 2004], to the best of our knowledge, no study has examined the impact of different vegetation coverage structures on UHI. As pointed out in [*Voogt and Oke*, 2003], most UHI studies so far examine qualitative or statistical relationship between the surface condition and UHI intensity, in which UHI-associated physical processes has not been investigated.

2. Objectives, Scientific Questions and Hypotheses

The overall purposes of this proposed study are to characterize UHI in the four Texas' metropolitan areas (Houston, Dallas-Fort Worth, San Antonio, El Paso) using satellite remote sensing data available from the 1980's to present, to understand the effect of urban development, vegetation coverage, parkland structures on UHI, and to provide baseline data and recommendation to local governmental agency for planning of sustainable urban development. We are going to test three scientific hypotheses: (1) Land use and land cover change through urbanization has contributed significantly to UHI, local and regional climate and air quality characteristics, which are closely related to human health, quality of life and environmental sustainability; (2) factional pervious surface and population density are two major factors in controlling the UHI intensity; and (3) differences in climate regime, city size, latitude, industry structure, and distance to ocean are factors in controlling starting and ending times of UHI in each year, shape and size of each UHI, and other UHI characteristics.

To test those hypotheses, we need to answer following scientific questions. These questions include: (1) whether there is significant difference of UHI due to different land use and land cover types, patterns and change; (2) if yes, to what degree the UHI is; (3) whether there is a significant difference of UHI intensities, with factional pervious surface and population change based on the four Texas cities; (4) if yes, to what degree the UHI intensity differs; (5) whether there is change in starting time and ending time of UHI in each year, due to the differences in climate, city size, location, industry of the four cities; (6) if yes, what are the differences; (7) whether there is change in shape and size of each of the four UHIs, due to the differences in climate, city size, location, industry of the four cities; (8) if yes, what are the differences; and (9) can we find a best setting of land use and land cover, pervious surface percentage, city size, population, vegetation structure, climate regime, and etc., in which the UHI is the minimum.

The specific objectives of this proposed study are to (1) comprehensively investigate UHI phenomenon in the four Texas cities, (2) examine the impact of land use and land cover, and other parameters on UHI effect and test our hypotheses, (3) predict UHI change due to selected future urban development scenarios (including urban expanding, parkland modifications etc.), (4) develop a general theory of the relationship between UHI intensity and urban environments.

3. Methodology

The UHI is embedded in a complex climate system influenced by many factors, including land use and land cover, altitude, proximity to the sea, sea breezes, gully wind, and parasol effect of Mt Lofty's orographic cloud (Schwerdtfeger 1976). It is challenging to isolate the contributions of various factoring agents. To achieve our research goals, we will incorporate multiple approaches in the study, including remote sensing, field measurements, numerical modeling, and geostatistical analysis. However, for this TRAC project due to the limited time range and funding support, we will only focus on using remote sensing data and geostatistical analysis to qualify the UHI of the four cities, examine the differences and similarities of the UHI in the four cities, and establish the relationship between different land use and land cover types and UHI, and between the different city setting and the UHI.

Remote sensing, with its spatial continuous data coverage, provides a good tool to study UHI [*Chen et al.*, 2006; *Hung et al.*, 2006; *Lo et al.*, 1997; *Streutker*, 2003; *Voogt and Oke*, 2003]. Satellite remote sensing data (free available from NASA, USGS, NOAA) will be used for the study. The variables we are going to investigate and derive include land surface temperature, fractional vegetation coverage, fractional pervious surface, NDVI, etc. With these data, we will be able to generate spatial, seasonal, and interannual variation of UHI in the study areas, and find the statistical correlation between UHI and others. Other data including 30 years of census data and basic GIS layers of each city will be collected and will be used for comprehensive analysis.

A preliminary study by PI Xie and his students (Xie et al. 2005), using MODIS/Aqua temperature products (1 km spatial resolution for both day time at 1:30 pm and night time at 1:30 am) from 2002-2005, indicated that UHI of the San Antonio downtown area was clearly shown in ~90% of the available cloud-free data during May to October of each year. It is especially prevalent in the night-time imagery than in the daytime imagery. During nighttime (daytime), the UHI is about 4 - 5 °K (6 - 8 °K) higher than the average T of the area and 6 - 7 °K (8 - 12 °K) higher than the rural area. Surprisingly, in the day-time imagery, the UHI phenomenon was found not only in the downtown area, but also several other small areas in the northern portion of City’s urban area, in specifically, (1) the area of Loop 410 between San Pedro and HWY 281 and (2) the triangle area among IH-10, Fredericksburg, and Wurzbach. Occasionally, UHI was also evident outside of the city’s urban area in the day-time imagery. The exact cause for this is not clear now. It could be related to rainfall events just prior to the image acquisition. Water or moisture of the bare/fallow agriculture lands evaporates faster than elsewhere with vegetation covered, thus resulting in higher temperature in those lands than elsewhere, a weather-caused false heat island. MODIS reflectivity data and weather radar (NEXRAD) rainfall data (Xie et al. 2005, 2006, Wang et al. 2007) corresponding to those dates will be used to study the hypothesis. However, all small UHI areas detected in the daytime imagery were not shown in the nighttime imagery. As expected, the water bodies have the highest T during the night-time and lowest T during the day-time. Figure 2 is an example of the night time temperatures provided by MODIS/Aqua satellite. The UHI in the downtown area are clearly mapped, with temperature gradually decrease towards rural area, while the four major water bodies (Canyon Lake to the northeast, Medina Lake to the west, Braunic Lake and Calaveras Lake to the southeast of the city) have the highest temperature for water has the best heat capacity.

In the proposed study, two graduate students (one student for San Antonio and Dallas-Fort Worth, one for Houston and El Paso) will be supported (half time in the spring semester and full time in the summer semester) to use this type of imagery from the 1980’s to present and other required datasets (census data and GIS layers, etc.). The pattern, distribution, extension, starting and ending dates of each year, intensities, and other characteristics of the UHI in both cities will be quantified. Then the differences and similarities of the UHI in four cities can be defined, and thus the relationship between the land use and land cover and UHI, between fractional pervious surface and UHI, between population and UHI, and many others such as city size, location and UHI, can be established.

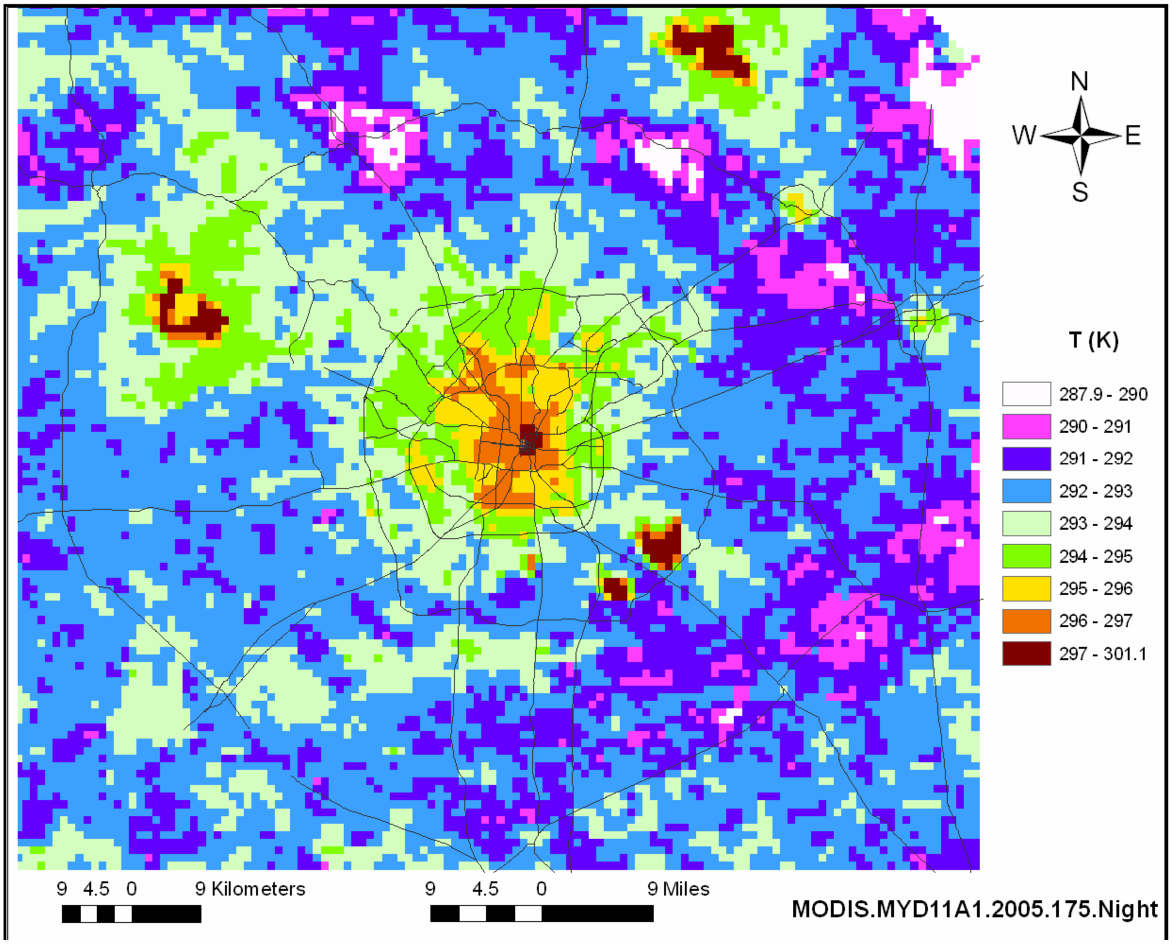

Figure 2. MODIS derived nighttime (1:30 am, CST) land surface temperature map on 6/24/2005, San Antonio, TX. The UHI is clearly shown in the downtown area. Four lakes surrounding the city have also the highest temperatures.

4. Expected results of the TRAC study

(1) Heat island characterization maps (in GIS-Geographic Information System format) of the four Texas metropolitan areas, providing baseline micrometeorological dataset for monitoring future changes due to climatic variation and change or anthropogenic changes (e.g., population increase and urban development, etc.)

(2) Seasonal variability, interannual variability and change (if there is) of UHI of the four metropolitan areas

(3) Quantitative description of vegetation coverage in mitigation of urban heat island effects and its temporal variations

(4) Generalization of land use and land cover impacts on UHI, and recommendation of practical city models (environmental settings) for future urban development

(5) Recommendation for future research and subsequent project scoping

(6) Several conference papers and journal papers summarizing above results.

5. Relevant to UTSA's Strategic Plan

This proposed project is directly related to UTSA's strategic plan for research and education in five areas of excellence, in specially, the **Energy and Environment** and **Sustainability**. Urban heat island (UHI) is the effect due to the environment change and urbanization. The increased temperature not only leads to adverse climate, but also drives up energy use for air conditioning and the pollution level. UHI impacts many natural, societal, and economical aspects, including biodiversity, energy consumption, living condition, human health, weather and climate patterns, and among others. Those are directly related to the sustainability of our resources, infrastructure, and heritage for future generations. Two graduate students will be supported for the projects. Based on the TRAC study, we will seek further funding from NSF, NASA, local government, etc. to continue the project and to extend it far beyond the TRAC study.

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