Mapping the LST (Land Surface Temperature) with Satellite Information and Software ArcGis

Ruth Maria Grajeda Rosado¹ a, Elia Mercedes Alonso Guzmán² b, Carlos Javier Esparza López³ c, Wilfrido Martínez Molina² d e, Hugo Luis Chávez García² e, Eduardo Limón Yedra⁴ f

¹Professor of the Universidad Veracruzana, School of Architecture and student of the Inter-Institutional Doctorate Program at the Michoacán University of San Nicolas de Hidalgo, Morelia, Michoacan, Mexico, 5804
²Materials Department, Civil Engineering Faculty, Universidad Michoacana de San Nicolas de Hidalgo, Morelia, Michoacan, Mexico, 58040
³Research-Lecturer, Head of Master in Bioclimatic Architecture UCO-CA25 Arquitectura y medio ambiente / Architecture and environment Research Unit, Facultad de Arquitectura y Diseño, Universidad de Colima
⁴Student of the Veracruz University of the Faculty of Construction Engineering and Habitat.

a ruthgrajeda10@yahoo.com.mx, b eliamercedesalonso@gmail.com,
c cesparza@ucol.mx, d wilfridomartinezmolina@gmail.com,
e hchavezenator@gmail.com, f yedra314@gmail.com

Abstract. This document describes the procedure to calculate the LST (Land Surface Temperature). The series of steps and equations is described using the thermal bands offered by the LandSat 8 satellite and the ArcGIS program tools. Although there are other methods and tools this procedure explicitly breaks down the use of information.

1. Introduction
The first official reports of urban climatology made in the city of London by Luke Howard, a century ago, have shown an increase in the urban area with respect to the rural area [1], at that time this increase was attributed to the intense fuel consumption in the city. Nowadays, the inhabitants look for new ways of monitoring the climatic, environmental, economic and social conditions within the cities, to obtain accurate data that suits their needs.

However, the growth of cities has increased exponentially in the last three decades. Faced with this, warnings about climate change emerge due to the alarming report of the United Nations Organization regarding the demographic behavior in the cities, because “54 percent of the world's current population lives in urban areas and it is predicted that by 2050 will reach 66 percent ... “, [2]. Intellectual work in technical areas such as climatology, architecture, urban planning or remote sensing should be applied with an ecological conscience aimed at predicting and solving the problems they cause in order to solve the urban-consumer environment. Currently 75% of the planet’s energy resources are consumed in large cities, causing the highest percentage of environmental deterioration in the form of pollution and gases that induce climate change [3].
The phenomenon of the Island of Urban Heat (IUH) has motivated architects, urban planners and engineers to analyze how heat transfer is generated within urban and suburban areas. Factors such as wind, population density, construction materials, vegetation, land use, are some of the typical ones that researchers have considered. A method of much use to determine the IUH isotherms has been calculating the Superficial Island of Urban Heat (SIUH) through the Land Surface Temperature (LST).

The EarthExplorer platform of the United States Geological Survey (USGS) provides free access for the download of Landsat satellite images from Mexican territory. The OLI (Operational Land Imager) and TIRS (Thermal Infrared Sensor) sensors are instruments on board the Landsat 8 satellite, which was launched in February 2013. From the page https://earthexplorer.usgs.gov/ the images taken by the satellite are discarded specifying the name of the region or area of analysis as well as the date, it should be mentioned that generally the satellite makes two shots per month.

2. Description of the Method
1) Using the ArcGIS program loads the images (thermal bands) Lansat 8 and the metadata, pressing "add data" selects the bands with the ending "B2, B3, B4, B5, B10 and B11" and the metadata "MTL", the last one in ".txt" format (figure 1).

![Figure 1. Add data from ArcGis.](image1)

For practical purposes, a clipping of the analysis area is done, with the "clip" tool, which will cut what is inside the work area, the tool is in the top menu, (windows-image analysis) will be displayed a window in which the bands should be selected and use the trimming tool (image analysis - processing - trimming). This creates a series of new layers in the table of contents, indicated by the word "clip" at the beginning of the name. The following new files will be used in the future, replacing the originals (figure 2).

![Figure 2. Using the tool clip and image analysis.](image2)
To create an RGB image (network, green, blue) from the combination of bands 2, 3 and 4, to visualize the analysis area. In order that the constructed image has the right color, the bands must be arranged in a specific order (4,3,2). This is provided directly with the right mouse button over the composition (layer-function properties-composite layer functions) (figure 3a). In the tab "composite bands" the order of the bands is exchanged using the arrows (figure 3b).

2) The calculation of the radiance of the thermal bands 10 and 11 (TIR bands) is achieved using the "raster calculator" (figure 4a), located in the menu (ArcToolBook - Spatial Analyst tools - Map algebra - Raster Calculator). Where the equation applies:

$$\text{TOA (L)} = M_L \times Q_\text{cal} + A_L$$  \hspace{1cm} (1)

Where:
- $M_L =$ Specific multiplicative scaling factor of each band. Value obtained from the MTL metadata file under the name of "RADIANCE_MULT_BAND_X".
- $Q_\text{cal} =$ Is the band or the cut of it.
- $A_L =$ Value included in the MTL metadata "Radiance_Add_Band_X", where X corresponds to the number of the band (figure 4a).

This equation must be applied to bands 10 and 11, transferring this information to the raster calculator (figure 4b) like this: Radiance_Mult_Band_X * BAND_TERMICA_X + Radiance_Add_Band_X, as a result of this equation a new "radiance" image is generated.

3) The brightness temperature (BT) is the next step. The equation used is:

$$\text{BT} = \left( \frac{K_2}{\ln \left( \frac{K_1}{L} \right) + 1} \right) - 273.15$$  \hspace{1cm} (2)
Where:
• $K_1$ and $K_2$ = Conversion constants, included in the metadata ($K_1\_CONSTANT\_BAND\_x$ and $K_2\_CONSTANT\_BAND\_x$) apply to each band, 10 and 11.
• $\ln$ (natural logarithm) = Function in the raster calculator.

The results are given in the unit of Kelvin degrees, if the user wishes to convert it to Celsius degrees, the formula must incorporate the value 273.15. This equation must be done by substituting the values corresponding to bands 10 and 11. As in the previous case, the result of this operation will generate an output raster for each thermal band (figure 5).

To combine the temperature layers with the thermal bands (TemBrillo 10 and TemBrillo11) and obtain only one, we use the cell statistics tool located in ArcToolBox - Spatial Analyst tools - Local - Cell Statistics. It displays a window in which the images obtained as a result of the use of the raster calculator (TemBrillo10 and TemBrillo11) must be dragged. The name of the output raster must be specified (figure 6).

4) The following is to calculate the NDVI (Normal Difference Vegetation Index), for this bands 4 and 5 are used, applying the raster calculator, the equation is as follows:

$$\text{NDVI} = \frac{(\text{Band 5} - \text{Band 4})}{(\text{Band 5} + \text{Band 4})}$$  (3)

The data obtained is required to obtain the proportion of vegetation ($P_v$), of the next step. The degree of coverage or proportion of vegetation is calculated by the equation:

$$P_v = \text{Square} \left(\frac{(\text{NDVI} - \text{NDVI}_{\text{min}})}{(\text{NDVI}_{\text{max}} - \text{NDVI}_{\text{min}})}\right)$$  (4)

Where:
• Square = Corresponds to squaring the formula
• $\text{NDVI}_{\text{max}}$ = Maximum values visible in the "table of contents"
• NDVImin = Minimum values visible in the "table of contents"

5) The value of the emissivity, as a last step, is obtained with the raster calculator, introducing the following equation:

\[ e = m \times P_v + n \]  \hspace{1cm} (5)

Where:
• \( m \) = value of emissivity of vegetation, in this case 0.004 was used
• \( P_v \) = corresponds to the percentage of vegetation
• \( n \) = Soil emissivity value, in this case 0.986 was used
• Substituting remains:
  \[ LSE = 0.004 \times P_v + 0.986 \]

Figure 7a. Raster calculator tool for calculate the NDVI (left) and Figure 7b. for calculate the emissivity (right).

6) Finally, the Land Surface Temperature (LST), is applied with the equation:

\[ LST = \frac{BT}{1 + w \times (BT/p) \times \ln(\varepsilon)} \] \hspace{1cm} (6)

Where:
• \( BT \) = Brightness temperature (band 10 or 11 depending on the case)
• \( w \) = Length of the emitted radiation (band 10 or 11 as the case may be)
• \( p \) = Constant value obtained by the formula \( h \times \varepsilon / s \) that when substituting the values is 1.438 \( \times 10^{-34} \) Js and results in 14,380 and \( \varepsilon \) is LSE obtained previously, this equation should be applied in bands 10 and 11 separately for later unify the results with the tool (cell statistics)

Each equation that is made in the raster calculator generates an output raster which must be named and can be in a specific folder (figure 8a, 8b).

Figure 8a. Raster calculator tool for calculate LST (left) and Figure 8b. Corresponding land surface map of Veracruz, Mexico registered on May 21, 2018 (right).
3. Applications
The detection of the Land Surface Temperature (LST) in a city, besides determining the isotherms of the Superficial Island of Urban Heat (SIUH), allows to focus mitigation measures such as the reforestation of the zones to improve the evapotranspiration, the adequate distribution of the land use and the balanced of physical-thermal characteristics (emittance and albedo) of building materials. Examples of this are the works of [4-6].

Reference
[1] Gartland L M 2008 Heat Islands—Understanding and mitigation heat in urban areas, London: Routledge.
[2] ONU. (July 10, 2014). Department of Economic and Social Affairs. http://www.un.org/es/development/desa/news/population/world-urbanization-prospects-2014.html
[3] Yeang K, Richards I 2007 Eco Skyscrapers I, Images Pub. 1.
[4] Tomlinson C J, Chapman L, Thornes J E, Baker C 2011 Remote sensing land surface temperature for meteorology and climatology: A review, Meteoro. App. 18(3) 296-306.
[5] Anderson M C, Allen R G, Morse A, Kustas W P 2012 Use of Landsat thermal imagery in monitoring evapotranspiration and managing water resources, Remo. Sens. Enviro. 122 50-65.
[6] Mia Md B, Bromley C J, Fujimitsu Y 2012 Monitoring heat flux using Landsat TM/ETM+ thermal infrared data—A case study at Karapiti (‘Craters of the Moon’) thermal area New Zealand, J. Volcano. Geother. Res. 235-236 1-10.