University of Texas at San Antonio
EES 5053
Term Project

CORRELATION BETWEEN NDVI AND SURFACE TEMPERATURES USING LANDSAT ETM + IMAGERY

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Introduction and Objectives

The present study is a correlation between the Normalized Difference of Vegetation Index (NDVI) and Land Surface Temperatures for the area of San Antonio, Texas by using a satellite image from Landsat 7 ETM+ (Enhanced Thematic Mapper).
Since satellite borne imagery can provide a better low cost tool for environmental studies such as urban climate, we will not do any in-situ measurements for vegetation cover or surface temperatures.
This study is a part of a remote sensing class (EES 5053) hence we will be using the university laboratory and image processing software (ENVI).
Previous researches and studies were conducted in this topic, at different scales and objectives, they all agree on the existence of a very close relationship between NDVI and LSTs (Dousset & Gourmelon 2003, Weng et al. 2004).

Site and date acquisition

The site of the study is the urban area of San Antonio, Texas and it's surroundings, the image was downloaded from TexasVeiw .org under the path 40 row 39 (figure 1) with a resolution of 30 X 30 m, the image was obtained in the 21 of June 2001 at 11.00 am local time, the study area comprised between latitudes 29.366541 and 31.207792 North and the longitudes 97.184379 and 98.585690 West, the cloud cover was near 0 % at recording time.

Satellite specifications

Landsat 7 ETM+ (Enhanced Thematic Mapper) is the latest of NASA's earth observation satellites, it was launched on April 15 1999, and it has a sun-synchronous orbit, its sensor specifications are listed below:
Spectrum coverage (8 bands) Visible, Near Infrared, Thermal Infrared
Spectrum resolution 50 – 200 m
Spatial resolution 15, 30, 60 m
Spatial coverage 185r Km (swath) or global
Temporal resolution and coverage 16 days, 4/15/1999 through present
Radiometric resolution and coverage 8 Bits, 0 to 255.

Methodology and image processing procedures

The image was delivered corrected and projected, no atmospheric corrections were needed; our methodology can be summarized in the next steps, and the entire Project is summarized in the flow chart of Figure 2.

1- Radiance retrieval for bands Visible, NIR and TIR
2- Reflectance retrieval for bands Visible and NIR
3- NDVI calculations from Visible and NIR
4- Brightness temperatures retrieval from TIR
5- Land surface temperatures retrieval from last step
6- Land Use and Land Cover image classification
7- NDVI image classification
8- LSTs image classification
9- Statistical parameters
10- Correlation between NDVI and LSTs
11- Discussion of results

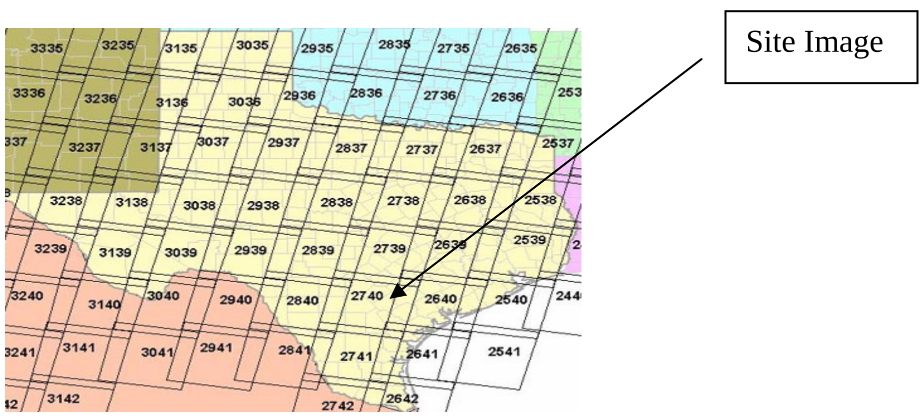

Figure 1: Localization of the study area ETM+ path 27 row 40, June 21 2001.

-Radiance Image retrieval

Landsat satellite images and most of remote sensing satellite stores information about each pixel as a Digital Number (DN), this means that all data information is stored digitally as a binary number. In order to retrieve the spectral radiance we need to convert the DN to radiance by using Band Math, some additional parameters are needed to do the calculations, such as the Offset and the Gain for both bands 3 and 4(Visible and NIR respectively) these two parameters can be find in the header file for the image.
The next formula is used for the conversion of DN to radiance:

$$L_{\lambda} = gain * DN + Offset$$

Where L_{λ} Is the band used or the wavelength of emitted radiance
$gain$ Is 0.619216 for band 3 and 0.965490 for band 4

Offset is -5.0 for band 3 and -5.10001 for band 4

-Reflectance retrieval

The reflectance for the two bands is calculated using the formula of Markham and Baker:

$$\rho_\lambda = \frac{\pi * L_\lambda * d^2}{Esun_\lambda * \cos\theta}$$

Where $Esun_\lambda$ Is the mean solar atmospheric radiances for band L_λ

$\cos\theta$ Is the cosine of the solar incident angle (64.36^0)

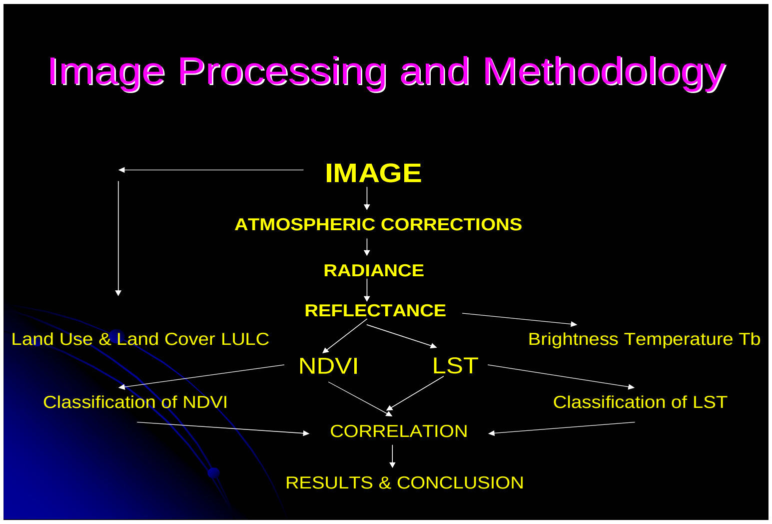

Figure 2: Flow chart showing study procedures

-NDVI image retrieval

We calculate the NDVI using the reflectance for band 3 and band 4, the formula below is used for this matter:

(NIR-RED) / (NIR+RED)

-Brightness temperatures retrieval:

Satellite TIR sensors measure top of the atmosphere (TOA) radiances, from which brightness temperatures (also known as blackbody temperatures) can be derived using Plank's law (Dash et al. 2002).

Landsat ETM+ stores brightness temperatures in the thermal infrared band (band6), which is obtained from the radiance of the same band (same procedures are used above) these temperatures are noted T_b, the next formula is used for calculations:

$$T_b = \frac{K_2}{\ln(\frac{K_1}{L_\lambda} + 1)}$$

Where K_2 and K_1 are pr-launch calibration constants.

T_b Effective at-satellite brightness temperatures in degrees Kelvin.

Brightness temperatures T_b are corrected spectral emissivity values prior to the computation of LSTs , in our case only one emissivity is used (0.098).

$$S_t = \frac{T_b}{1 + (\lambda * T_b / \rho) \ln \varepsilon}$$

Where $\ln \varepsilon$ is the neperian logarithm for emissivity ε.

ρ Is a sensor calibration constant.

-Land use and Land Coverage Classification LULC

From the initial row image we use an unsupervised classification , with 10 classes as a beginning, comparisons between the different classes and verification based on our knowledge of the area of San Antonio enable us to limit the number of classes to six which are: 1)Water 2) Mixed crops and grass 3) Urban- Commercial and roads 4)Fallow land 5)Concrete structures and limestone 6) high density vegetation (Forest), the resulting image for this classification is shown in figure 3.

-NDVI image classification

Using the density slice on the resulting NDVI image, we were able to derive 8 classes as shown in figure 4, NDVI values are included in the range -1 to +1, during our study we found several image pixels beyond these range, so we eliminated this values (4 Pixels) assuming that this was a result of image bad data values.

-LSTs image classification

Same procedure is used for the LST image classification, with 12 resulting classes, the number of classes was chosen in order to reflect the maximum temperatures variations through the entire image and especially to show the difference of temperatures between urbanized areas and vegetated areas, Figure 5 illustrate this classification.

-Statistical Parameters

Both NDVI and LST images classes were used to retrieve some statistical about temperatures and NDVI for each LULC class; Unfortunately because of computer and software crashes (maybe due to an insufficient memory) only three classes had successful statistics (Tables 1 and 2). Therefore our analysis and conclusion will be limited to these classes.

Figure 3 Land Use and Land Cover Classification (LULC)

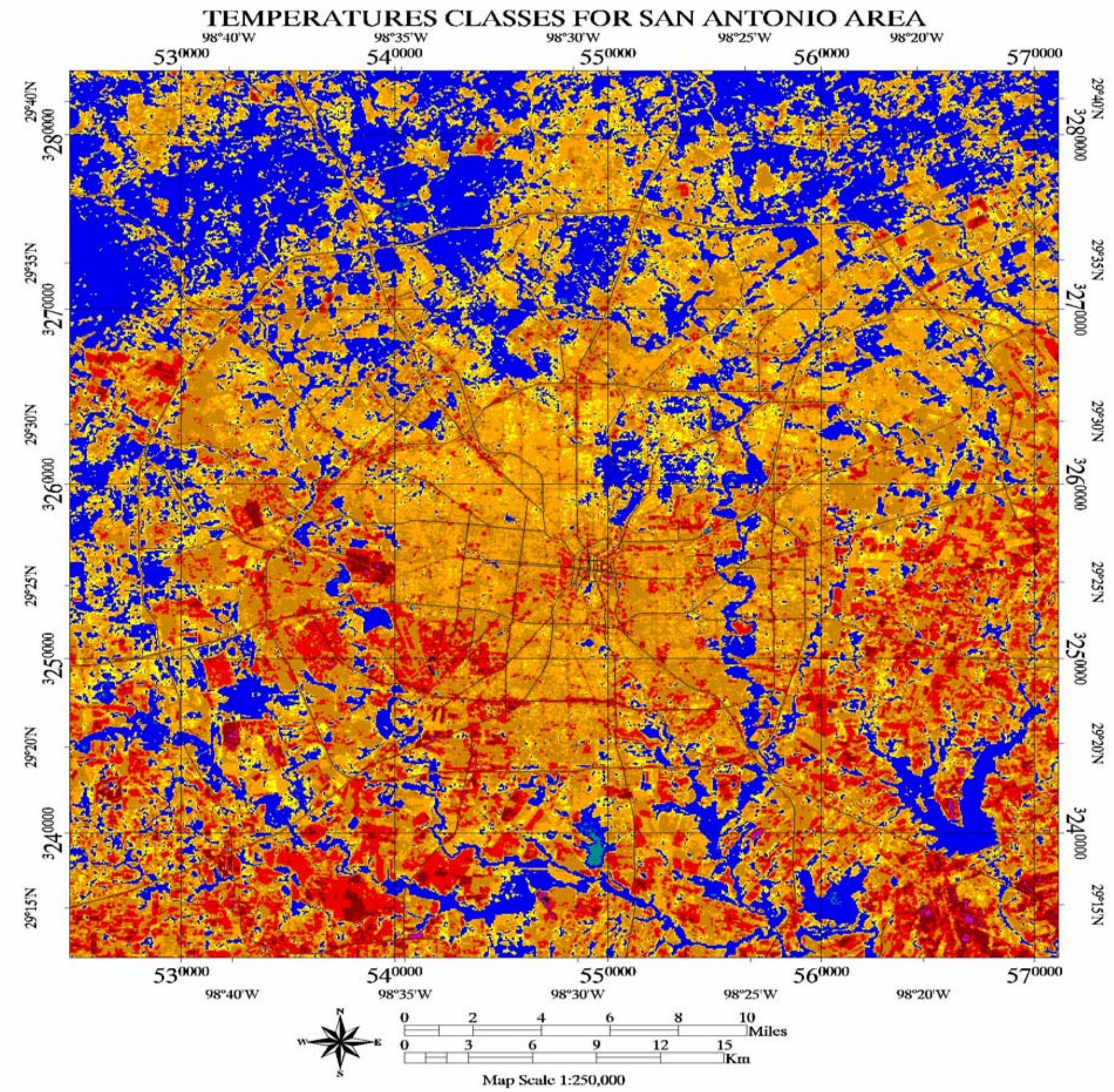

Figure 5 Land Surface Temperatures Classification

Table 1 Statistics for NDVI by LULC

CLASS	MINIMUM	MAXIMUM	MEAN	STANDARD DEVIATION
1	-0.915301	-0.858144	-0.563747	0.036549
5	-0.208327	0.225247	-0.329211	0.066439
6	0.107639	0.934441	0.757546	0.060163

Class 1 is Water, Class 5 is Concrete structures and Limestone, Class 6 is High density vegetation

Table 2 Statistics for LSTs by LULC (K)

CLASS	MINIMUM	MAXIMUM	MEAN	STANDARD DEVIATION
1	297.516418	322.615387	301.832989	2.084401
5	289.041107	321.200714	308.049680	2.384720
6	298.079437	319.053314	303.268963	1.415670

Class 1 is Water, Class 5 is Concrete structures and Limestone, Class 6 is High density vegetation

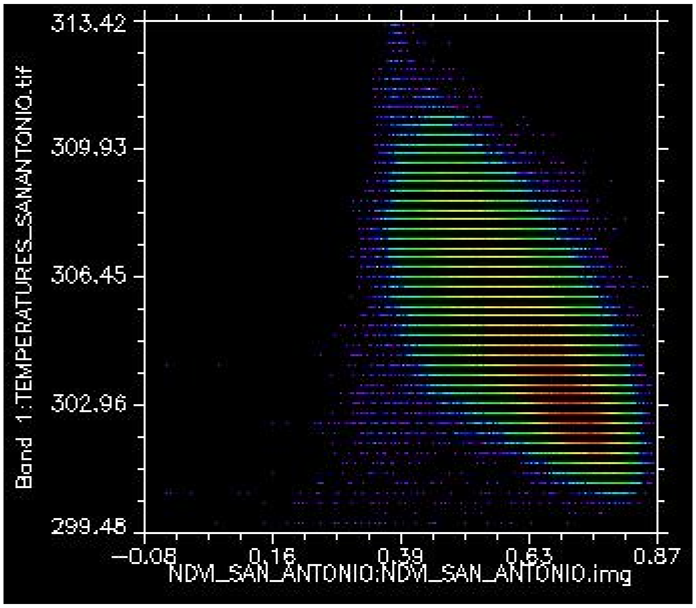

Figure 6 Correlation Plot between NDVI and LSTs

Results and Discussion

The NDVI image shows a difference in vegetation distribution in the region of San Antonio, the lowest values -0.95 are found in water bodies such as Lake Calaveras or Braunic Lake in the SE part of the image, after that is the urban areas, like downtown San Antonio and the old neighborhoods around it, the East side and the West side of town and parts of the Southside of the city, Concerning downtown which is a commercial and Business center, there low vegetation and a high concentration of roads and buildings. The East, West and South parts of the city are old residential area with little or very dispersed vegetation; the highest values of the NDVI are located North of downtown or in the Hill Country, in some cases in the northern residential neighborhoods, like Hollywood Park, Alamo Heights, Olmos Park , these are newer residential sites with a high vegetation density.

The LSTs image follows approximately the same distribution as the NDVI; the coolest pixels in the image are the water bodies or river beds and streams, followed by the heavy vegetated areas like the hill country or the northern neighborhoods cited above.
In both NDVI and LST images we notice the difference of the lower parts of the image, including downtown and the highest part of the image, which reflects the nature of the city.
The LULC image shows some black pixels as result of bad classification or unclassified points in the image, meaning that further refinement of the classification is needed; probably the use of SAM algorithm is better suited for this kind of classification.
The statistical results confirm our classified NDVI and LSTs images, lower values for Water, with the lowest standard deviation due to the physical properties of water (Thermal inertia), with a mean of 308 degrees Kelvin the concrete and limestone have the highest temperatures, then the high density vegetation followed by the water.
The NDVI statistics shows a negative values for water and concrete and limestone classes, the highest mean is found in the high density vegetated areas which is very expected result.
The correlation plot in figure 6 indicates a clear negative correlation between NDVI and LSTs, the coefficient of correlation is missing due to software problems in deriving statistics, and our inability at this stage to find other ways to correct this problem.

-Future Projections

The correlation between NDVI and LSTs seems at first as an easy task, but in reality it can be very complex process to do. The use of a single emissivity can introduce an error ranging form 1 to 4 K in LSTs calculations, plus the method used in here did not provide significant results in the spatial distribution of both NDVI and LST.
Other recent studies used more refined methods such as the Linear Spectral Mixture analysis (LSMA) and the Fractal theory for a more precise classification images, the use of Ground Vegetation Fraction seems to bring better results then the use of a simple NDVI extraction.
This subject can be an basis for a thesis research if some can get to all the details of vegetation spatial distribution, types and species and of course a more precise LULC classification.
A climatic and geomorphologic study of the area will enhance the methodology and it's efficiency.

-References

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