USING HEAT TO TRACK URBAN GROWTH IN THE CARIBBEAN

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ABSTRACT.— The approach of this investigation is to use the concept of "Thermal Remote Sensing". In essence, the purpose is to look for metropolitan/urban areas in the Caribbean especially in the Greater Antilles. The phenomenon of "Urban Heat Island" (UHI) is a key factor for which this paper looks for. There it has been seeing temperatures up to 10 degrees Fahrenheit higher in cities where UHI are notable. This "islands" are known for creating self contained weather even causing thunderstorms. Satellite remote sensing offers considerable promise for examining the dynamics of urban growth, and relating observed patterns to basic principles of socio-economics. It is clear that substantial variations exist in the rate at which cities have grown during the last several decades. These differences may relate to regional economic conditions, policy choices at the metropolitan level, or other physical geographic factors (Lisay and Masek, 2002). For this project, we considerate that the combination of spatial, spectral and time resolutions of MODIS along with the availability of abundant data for the sensor is considered to be more effective to monitor the regional heat environment associated with the land cover. Large cities like Atlanta, Georgia USA; Las Vegas, Nevada USA; Tokyo in Japan; and Bangladesh in India; Have already conducted studies to measure urban growth's patterns. However, this kind of research have been rarely conducted, or at least poorly documented in the Caribbean region. For that reason, our study will try to include main metropolitan areas in: Puerto Rico, Hispaniola, Cuba, Jamaica and others.

INTRODUCTION

In the last century, urban areas all over the world have experienced rapid and exponential growth. Growth of cities is related to changes in land, vegetation and regional climatic changes. More often than not, dramatic increase in temperature is closely related with rapid rate in urbanism.

The definition used when the term of "heat island" or "urban heat island" (UHI) is given by the Glossary of Weather and Climate:

"An area of higher temperatures in an urban setting compared to the temperatures of the suburban and rural surroundings. It appears as an 'island' in the pattern of isotherms on a surface map."

This means that a city with a higher temperature than its surroundings will appear as a prominent body in a thermal image, thus giving the resemblance of an island as a result of covering the ground with concrete and asphalt, as well as massive energy consumption. Those factors associated with the concentration of human activity are believed to cause rise in temperature in urban areas. The UHI is a mayor environmental problem; however, it can also be use to determine urban growth and population distribution.

In order study the UHI and the urban growth as well, MODIS sensor provides strong "ground base", as it provides with data in many channels in a variety of spectral bands. MODIS sensor has 3 different band spatial resolutions: bands 1 to 2 ¼ Kilometer, bands 3 16 ½ Kilometer, and bands 17 to 36 1 Kilometer. Bands 1 to15 are considerate to be in the visible region of the electromagnetic spectrum (EMS). Similarly, bands 16 to 19 and bands 20 – 36, are in the near infrared and far infrared portion of EMS respectively.

OBJECTIVES

The objectives of this project are:

- To compare heat of some cities in the Caribbean to determinate urban areas.
- To make a qualitative description of the rate of growth of cities based on their thermal emittance.
- To make use of data captured at Space Information Laboratory and use it for image processing.

METHODOLOGY

The data to be used has to bee processed from the raw format in which it is captures at the Space Information Laboratory, SIL (UPR – Mayagüez Campus), by SARPROC computer. The many processes can be subdivided in three main stages of refinement:

- Raw data – this include the process of capturing the data (if necessary) and identifying zones of interest, using VEXEL software.
- MODIS Preprocess – step consisting of eliminating instruments noises. Is in this step that the raw data can be processes in to a format that ENVI software can read: level 1-b.
- ENVI final processing, classifications, corrections (atmospheric, etc.), and emissivity calculations.

Two images to be compared have to be selected. The images have to be from two different dates, preferably allowing five years between images. Both images will be processed in the same manner, using the same corrections. This will allow us to compare them and to determine the urban growth. Although we intended to compare two images, the data that best suited manageable atmospheric conditions (without clouds) available is only a year apart. This makes almost impossible a time related scaled comparison. For this reason we selected two images from EOS MODIS with 1 km of spatial resolution: one from the Greater Antilles and one from Northern part of South America. The Greater Antilles Region's image was captured on April 22, 2003 at 15:37 GMT and the Northern South America Region's image was captured on February 11, 2002 at 15:07 GMT.

MODIS preprocessing will be done at the Space Information Laboratory, using the facility's personal to provide the preprocessed images. Preprocess is done using UNIX commands, and applying decompression algorithm (such as Red Solomon, etc.) to the raw image. The use of thermal infrared bands and the application of atmospheric corrections factors will be the main task to be held using ENVI. Although we intended to use ENVI 3.5 for processing the images, we confronted problems because the software does not contain a specific and/or specialized modules and tools for the processing of MODIS images. ENVI 3.5 opens only hdf files with 1 km spatial resolution, and asks numerous parameters of spatial resolution and number of bands for other of the hdf files produced by the level 1b preprocessing. We finally decided to use ENVI 3.6 to process MODIS images. ENVI 3.6 provided us the tools to open the hdf files and to work with them. Nevertheless, we could not calculate Emissivity or NDVI. NDVI specifically for MODIS images is not supported in this version of ENVI.

Two types of images format were managed in ENVI 3.6: geo/Tiff (Greater Antilles) and EOS/hdf (Northern South America). The geo/Tiff format is produced by processing from Level 1-B (hdf) to Level 2-A (geo/Tiff) at SARPROC's VEXEL program using a simple command line script[1]. An important feature of geo/Tiff image format is that it is already corrected for black current noise and other instruments related response, and it is georeferenced. If the format used is hdf we need to correct the image geometrically and georeference it using ENVI 3.6.

For each image we produced a false color image in ENVI 3.6 using band 6 for Red, band 5 for Green and band 4 for Blue (see appendix A). We also used band 29 (Emitted Radiation, 8.4 - 8.7 μm) in Gray Scale for each of the images, we applied an atmospheric correction and an ENVI color table scale (Red Temperature). Other false color images were produced using the thermal bands of MODIS: band 22 (3.929 – 3.989 μm) - Blue, band 29 (8.4 - 8.7μm) – Green, and band 31 (10.78-11.28 μm) - Red.

Using a map with cities through the Caribbean we identified the areas in the images and determined if the cities can be easily recognized. Using gray-scale images from the band 29, we focused in determination of specific patterns that distinguished cities from other features (crops, vegetation, bare soil, ocean, etc).

RESULTS & DISCUSSION

False color images of the bands 6-5-4 (R-G-B) with 500m of spatial resolution, provided us the capability to clearly distinguish the Greater Antilles (Cuba, La Hispaniola, Jamaica and Puerto Rico) and differentiated land from ocean and clouds.

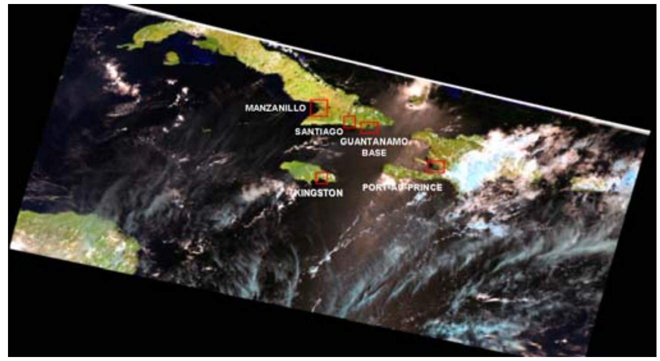


Fig-2: False Color Image of the Greater Antilles and the Caribbean using band 6 for Red, band 5 for Green and band 4 for Blue.

Using the same type of false color image for Northern South America we can clearly distinguished Venezuela, Colombia and Panamá and differentiated land from ocean, lakes, rivers and clouds.

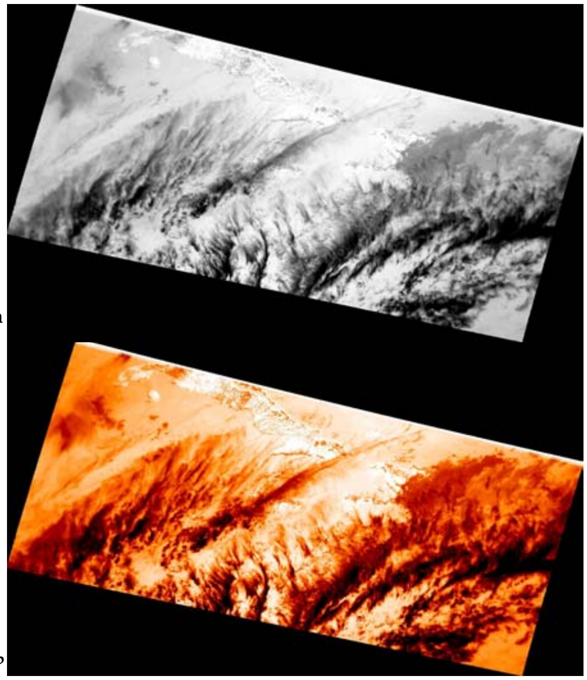
Fig-3: False Color Image of the Northern South America using band 6 for Red, band 5 for Green and band 4 for Blue.

For figures 1 and 2, green and browns describes land, black describes bodies of water and white and blue describes clouds. When we applied zoom in ENVI we can distinguished gray areas were important cities are located.

We produce a variety of images for the Caribbean and Northern South America regions using MODIS thermal bands of 1 km spatial resolution. In gray scale images using thermal band-29 we can appreciate the land zones and distinguish it from ocean and clouds (figures 4-a & 5-a). We applied ENVI color table scale (RED TEMPERATURE) to previous image to describe emissivity (figures 4-b & 5-b). On those images brighter tones represents warmer features and darker tones represents coolers features. We produce false color images of 1 km of spatial resolutions for the Caribbean (figure 6) and Northern South America (figure 7) regions using thermal bands 22-29-31 (R-G -B). Those images only served to visualize the relation between those bands, and as a visual source of thermal information for the region under study.

[1] **Instructions for MODIS images georectifying**. Space Information Laboratory. May 22, 2002.

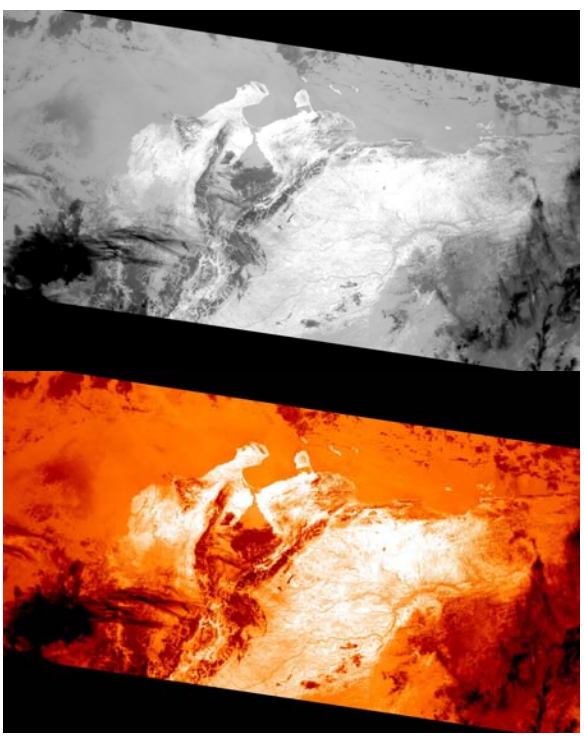
4a



4b

Fig-4: a-Gray Scale Image of the Greater Antilles and the Caribbean using thermal band-29 with atmospheric correction.
b-Red Temperature (ENVI's Color Scale) Image of the Greater Antilles and the Caribbean using thermal band 29 with atmospheric correction.

5a



5b

Fig-5: a-Gray Scale Image of the Northern South America using thermal band-29 with atmospheric correction.
b-Red Temperature (ENVI's Color Scale) Image of the Northern South America using thermal band 29 with atmospheric correction.

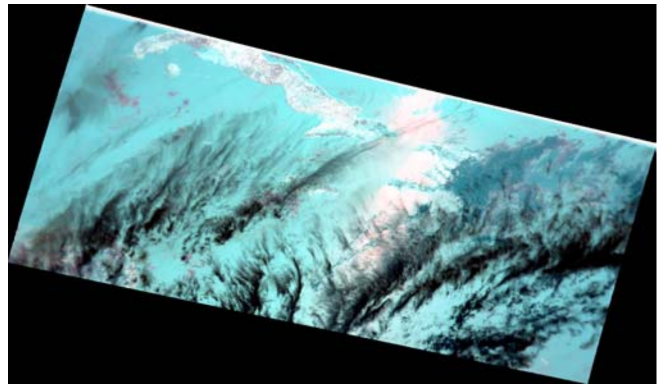


Fig-3: False Color Image of the Northern South America using band 22 for Red, band 29 for Green and band 31 for Blue.

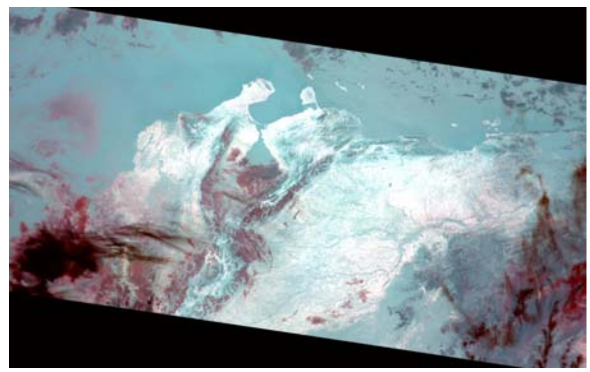


Fig-7: False Color Image of the Northern South America using band 22 for Red, band 29 for Green and band 31 for Blue.

CONCLUSIONS

MODIS data captured at Space Information Laboratory, can be processed at different levels so that it becomes suitable for ENVI 3.5 and 3.6. ***False Color Images*** (MODIS bands R-6, G-5, B-4) in ENVI 3.6 can be used to visually determine some of the urban areas in the Caribbean Region (cities are in gray color). By comparing ***Red Temperature Images*** (MODIS Thermal Band 29) with ***False Color Thermal Images*** we can visually correlate the images to determine the amount of emissivity in some urban areas in the Caribbean Region. We where not able to make a quantitative description of the rate of growth of cities based on their thermal emittance. We were not available to calculate the Vegetation Index. We could not quantitatively describe the Urban Heat Island Effect in the Caribbean. Although it may not be apparent in this project (because it is not fully developed); the MODIS Thermal Bands are used, along with ASTER Temperature Measurements, by the scientific community to calculate and monitor the Urban Heat Island, urban growth, and their environmental effects around the planet.

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APPENDIX A
MODIS BAND LIST DESCRIPTION

BAND #	RANGE nm	RANGE um	KEY USE
	reflected	emitted	
1	620-670		Absolute Land Cover Transformation, Vegetation Chlorophyll
2	841-876		Cloud Amount, Vegetation Land Cover Transformation
3	459-479		Soil/Vegetation Differences
4	545-565		Green Vegetation
5	1230-1250		Leaf/Canopy Differences
6	1628-1652		Snow/Cloud Differences
7	2105-2155		Cloud Properties, Land Properties
8	405-420		Chlorophyll
9	438-448		Chlorophyll
10	483-493		Chlorophyll
11	526-536		Chlorophyll
12	546-556		Sediments
13h	662-672		Atmosphere, Sediments
13l	662-672		Atmosphere, Sediments
14h	673-683		Chlorophyll Fluorescence
14l	673-683		Chlorophyll Fluorescence
15	743-753		Aerosol Properties
16	862-877		Aerosol Properties, Atmospheric Properties
17	890-920		Atmospheric Properties, Cloud Properties
18	931-941		Atmospheric Properties, Cloud Properties
19	915-965		Atmospheric Properties, Cloud Properties
20		3.660-3.840	Sea Surface Temperature
21		3.929-3.989	Forest Fires & Volcanoes
22		3.929-3.989	Cloud Temperature, Surface Temperature
23		4.020-4.080	Cloud Temperature, Surface Temperature
24		4.433-4.498	Cloud Fraction, Troposphere Temperature
25		4.482-4.549	Cloud Fraction, Troposphere Temperature
26	1.360-1.390		Cloud Fraction (Thin Cirrus), Troposphere Temperature
27		6.535-6.895	Mid Troposphere Humidity
28		7.175-7.475	Upper Troposphere Humidity
29		8.400-8.700	Surface Temperature
30		9.580-9.880	Total Ozone
31		10.780-11.280	Cloud Temperature, Forest Fires & Volcanoes, Surface Temp.
32		11.770-12.270	Cloud Height, Forest Fires & Volcanoes, Surface Temperature
33		13.185-13.485	Cloud Fraction, Cloud Height
34		13.485-13.785	Cloud Fraction, Cloud Height
35		13.785-14.085	Cloud Fraction, Cloud Height
36		14.085-14.385	Cloud Fraction, Cloud Height

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