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Quantitative Analysis of Factors Contributing to Urban Heat Island Effect in Cities of Latin-American Pacific Coast

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Abstract

Urban Heat Island Effect (UHI) is one of the most evident anthropogenic interventions on climate. During the last 20 years, a lot of research on monitoring and simulation of UHI was done by different institution across the world. However, there are some aspects not very clarified, for example, the decoupling and quantification of the different factors influencing UHI, depending on the location. In this paper, the Urban Weather Generator tool (UWG) is used to test the influence of some factors (density, vertical growth, loss of green, electricity and cars) on the resulting summer time UHI intensity in cities of the Pacific Latin-American coast.

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Keywords: *Urban Heat Island; Latin-America; Urban Weather Generator*

1. Introduction

Urban Heat Island Effect (UHI) is one of the most evident anthropogenic interventions on climate and is well studied worldwide. Some specific effort to understand the importance of each factor contributing to its formation has been done especially by researchers of the Asia-Pacific region. They identify three principal factors in the UHI formation: anthropogenic heat generation, impervious materials and urban geometry.

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The urban geometry effect could be divided in sub-categories, like radiation trapping, ventilation blockage, buildings' walls temperatures. In this paper the first factor, anthropogenic heat generation, is also decoupled in heat generated by traffic in the roads and heat generated by appliances and systems used in buildings. The importance of this subdivision is trying to quantify the weight of the electricity usage on the total UHI effect.

In South-American Pacific coast, average environmental temperatures depend strongly by the latitude. In Chile the influence of the Humboldt current makes the climate mild in summer, milder on the Ocean than in the internal valley. In Peru, average temperatures are higher, but also natural ventilation is commonly used as the main passive strategy to cool buildings (residential sector). In Ecuador things change: Guayaquil has a cooling demand for the building sector very high, due to the hot-humid climate location.

Latin American countries are experimenting intensive urban growth that traduces in morphological changes in the urban tissue. These changes, differently from other experiences (like European or North-American urban recovery), consist in general in: densification, vertical growth and loss of green areas. Moreover, as a secondary effect of this morphological change, interested areas experiment an important increase in electricity usage and in the number of cars (densification and vertical growth means more people, more cars, more elevators, etc.) This secondary effect is oversized by the increase in the acquisitive power of the "big middle class" of the South American continent. For example, the actual proportion of cars per person in South-America is about 0.15 cars per person, while the proportion in USA is 0.98 and in Europe 0.6. The region's growth seems to justify that in 20 years the population of the South-American countries will has the same possibilities of the so-called "developed world". Similar data regard the ownership and use of any kind of appliances, including air-conditioning units. Today, about the 10% of the population in Chile, Peru and Ecuador is commonly using heating and cooling systems, but this proportion is estimated to growth very fast in the next years.

Some studies underlined that these secondary changes could have an extreme impact on the energy consumption of the city, especially regarding commercial buildings [1,2]. However, the impact of the electricity usage on the urban weather has not been accurately studied yet for the South-American region. Some studies on the same topic have been developed in other world regions [3,4,5,6]. These studies generally emphasize both the possible importance of the building-based heat generation and the difficulty to decouple the factors generating UHI effect. Nerveless, general information about the modeling of the UHI effect is already available [7,8]. From these studies, what appears clear is that the influence of each factor depends on the specific location [9,10] with its own characteristics of rural weather, city morphology and cultural specificity.

The Urban Weather Generator (UWG) is a tool developed at the Massachusetts Institute of Technology (MIT) [11,12,13,14] with the scope to help in simulation of urban weather scenarios. UWG is useful for example in building performance simulation, assuring a more accurate evaluation of the buildings' performance by using the UWG produced urban weather file instead of a rural weather file.

The tool couples a building simulation module with a canyon scale atmospheric simulation module. The result is a weather file with modified temperatures in the urban canyon. A lot of parameters are considered by the tool, these could be divided in construction parameters (wall, roofs, glazing properties – with especial attention focused on the albedo and emissivity materials' properties); building parameters (internal gains, ventilation, infiltration, set-points, efficiencies of the systems); urban morphology parameters (density, height, façade ratio respect to site, tree coverage, non-buildings anthropogenic heat generation); reference site (latitude, longitude, weather parameters). Sensitivity analyses of the tool parameters are undergoing, but it is clear that the urban parameters, the albedo, the emissivity and the anthropogenic heat generation in the canyon are key factors [15].

In this paper, the UWG tool is used to test the influence of the described main factors (density, vertical growth, loss of green, electricity and cars) on the resulting summer time UHI intensity. Results show the importance of the electricity usage on the resulting UHI effect (after heat generation of cars and changes in density), and the influence of the natural ventilation potential to both evacuate the urban heat and to reduce the cooling needs. Natural ventilation should be considered as an important strategy in mitigation of UHI, in addition to cool surface materials and city greening. Urban form and natural ventilation are connected to electricity (especially HVAC) usage patterns, mainly through the breeze deviations in the urban canopy and the consequent buildings' capacity to use it to cool inside.