Implications of Urban Form and Topography in Thermal Conditions at Local and Micro Scale in a Tropical Urban Area Located in a Valley

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November 21, 2022

Abstract

Cities are the most sensitive and vulnerable places to climate variability and change and weather-related extreme events given high population density, with the aggravating factor that urban climate also suffers modifications due to the widespread replacement of the natural surface altering the local thermal conditions. The Aburrá Valley is a narrow valley located at the tropical Andes in northern South America with urban areas between 1300 and 2000 m.a.s.l, a population of approximate 3.9 million people, and a comfortable climate relative to standard indoor conditions. In this work, we examine observed weather patterns in the local scale and the urban canopy layer (UCL) using data from weather stations at sites with different surface features regarding vegetation/non-impervious fractions and urban structure (Sky View Factor SVF). UCL data is available from two data sources, the first one from a field campaign using all-in-one weather sensors at the valley´s bottom, and the second one from a low-cost sensor network with robust temperature and humidity data as part of a local citizen science project with measurements in a diverse altitude range. Results suggest that at the local scale there exist different climate mean conditions due to altitude, with significant weather variability depending on radiation levels and rainfall occurrence, but at the same time, the urban effects are evident since the lowest altitude stations do not necessarily register the highest temperatures depending on the local characteristics. UCL measurements show that, while the altitude defines a background state, there are notable differences between places mainly influenced by insolation changes due to vegetation around and above sensors. Currently, the local population does not perceive thermal stress as a risk factor because it is not difficult to find places with appropriate thermal conditions when thermal discomfort arises. However, this research is relevant considering the projected local surface temperature increase due to climate change and the inexistence of baseline studies assessing the thermal comfort in outdoors to support local adaptation actions. The results of this study are useful for urban planning and building design to improve thermal conditions, especially in open spaces.

Implications of Urban Landscape and Topography for the Thermal Conditions in a Tropical Urban Valley

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Introduction

- Cities are the most sensitive and vulnerable places to climate variability and change and weather-related extreme events.
- Does a complex terrain implies different climates in a city? Cities also modify climate!

Goal

Describing the thermal environment to which the urban population of the Aburrá Valley is exposed.

Valle de Aburrá: a tropical urban area in a complex terrain

Narrow valley located at northwestern of **Colombia**, with **urban** areas between 1300 and 2000 m.a.s.l.

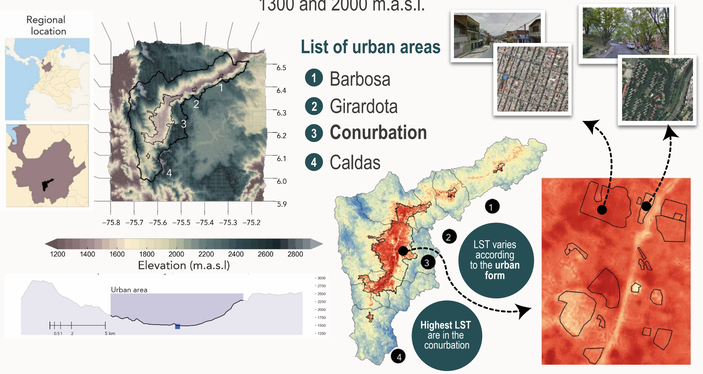
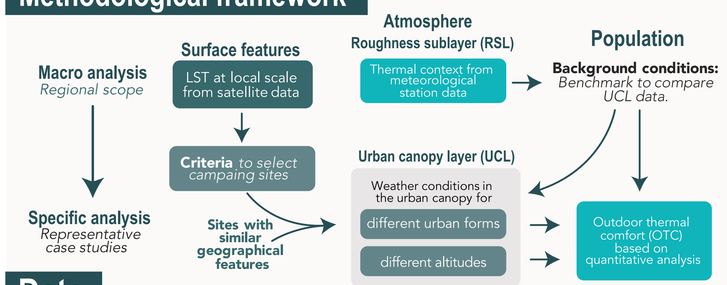


Figure 1. Left: Geographic context and cross section of the widest area in the Valley. **Right:** Land Surface Temperature (LST) from Landsat 8, and examples of neighborhoods with contrasting urban architecture.

Methodological framework



Data

Figure 2. Left: Automatic weather station network. **Right:** Schematic diagram of UCL measurements.

Climatological thermal context

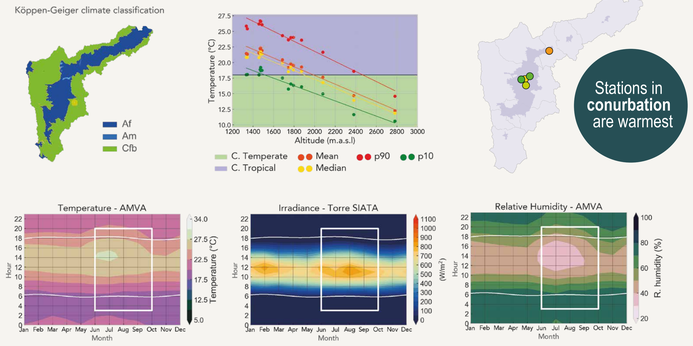
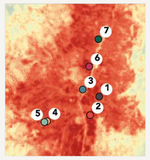


Figure 3. From left to right: Climate zones classification, station altitude vs. temperature, annual diurnal cycle of radiation, temperature, and relative humidity from a sensor located within the conurbation

There are **different climate regimes** within the valley. Stations located within conurbation register the highest temperatures. The amplitude of the diurnal cycle is larger than the annual cycle.

Urban canopy: case of study

different urban forms



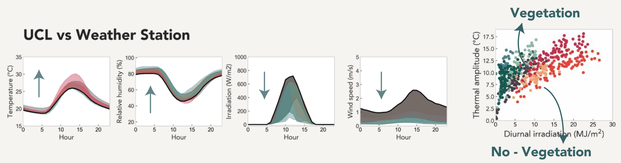
Measurement campaign with all-in-one sensors

Are there differences in the thermal conditions reported by weather stations and those where the population lives?

Closed urban canyon — Site 1

Places with little or no vegetation — Site 2, Site 4, Site 6

Sites with vegetation — Site 3, Site 5, Site 7



Black line: weather station

Figure 4. UCL measurements compared with weather stations. Relationship of thermal amplitude with diurnal irradiation in each place.

UCL tends to be warmer and more humid.

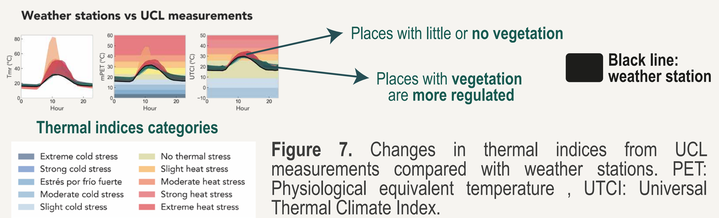
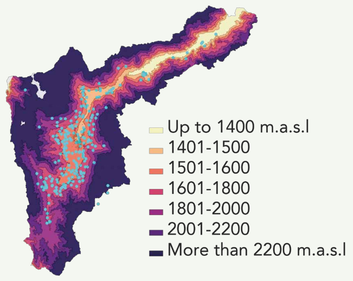


Figure 7. Changes in thermal indices from UCL measurements compared with weather stations. PET: Physiological equivalent temperature , UTCI: Universal Thermal Climate Index.

Urban canopy: back to regional

different altitudes



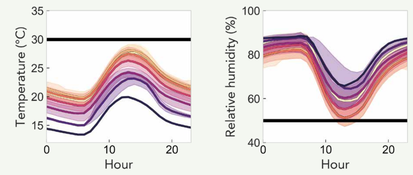
Science Citizen project: Ciudadanos Científicos V2

250 Sites measuring PM2.5, temperature, and relative humidity.

Most sensors installed in:

- 1-4 story buildings
- In the 1400-1800 m.s.n.m altitude range (Af climate zone).

Diurnal cycles – all data



Altitude vs Temperature in UCL and RSL

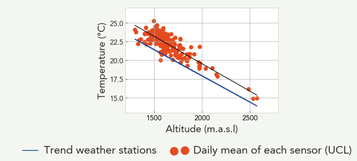


Figure 5. Left: Diurnal cycles of temperature and relative humidity by altitude range. **Right:** Temperature - altitude scatter plot compared with automatic weather station network temperature- altitude trend.

Compared with weather stations, the UCL is warmer and more humid.

Psychrometric Diagram: Diurnal cycles relative to altitude

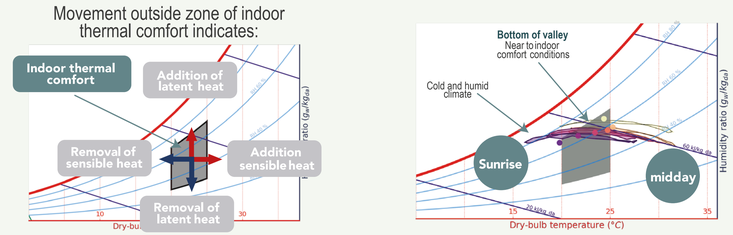


Figure 6: In all altitude ranges there are important changes throughout the day , mainly associated with sensible heating. Possible heat stress is associated to radiation peaks.

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Overall conclusions and future work

- Altitude defines a background climate in the Aburrá Valley, but the urban heat island effect is a notable.
- Microclimate differences are influenced by solar access and vegetation around and above sensors. Sites with vegetation show better thermal regulation.
- The thermal conditions suggest the possibility of heat stress in various zones in the region. There is a need to include a qualitative assessment of OTC to support local climate change adaptation actions.

Acknowledgements

This work was supported by Area Metropolitana del Valle de Aburrá, Municipio de Medellín, Grupo EPM, and ISAGEN under the contract CD511, 2017. Gisel Guzmán was partly funded by Universidad Nacional de Colombia under the Facultad de Minas graduate scholarship program. The authors would also like to acknowledge the use of free software including Python and Matplotlib.

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