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First results of the data acquisition and analysis of microclimate conditions in Barranquilla, Colombia

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1. Introduction

The change of urban climate influences how cities will develop in the future, not only because of the impact on the energy consumption of buildings or on the environment, but also on human thermal comfort. For growing cities in tropical climates, urban microclimate becomes a relevant aspect for the design and planning of future developments. Urban 'climate-sensitive' design is defined as a process that considers the fundamental elements of microclimates (e.g., solar radiation, wind, air temperature) for design purposes. This concept is applied not only to benefit from the existing urban microclimate but also to mitigate it's already stressed conditions and decrease the negative effects through design and planning [Tapias and Schmitt, 2014]. However, this concept requires a more scientific approach to evaluate its true meaning [Berger, 2014], which implies a method of inquiry that must be based on empirical and measurable evidence subject to specific principles of reasoning [Tapias and Schmitt, 2014].

Outdoor spaces are important for cities as these provide daily pedestrian traffic and different outdoor activities contributing to urban liveability and vitality [Chen and Ng, 2011, Fröhlich and Matzarakis, 2013]. Among many factors that determine the quality of outdoor spaces, the urban microclimate is an important one. Pedestrians are directly exposed to their immediate environment in terms of variations of air temperature, relative humidity, wind speed, and solar radiation. Therefore, people's sensation of thermal comfort is greatly affected by the local microclimate [Chen and Ng, 2011, Ketterer and Matzarakis, 2014].

The degree of impact of outdoor thermal environment on thermal comfort varies with the thermal requirements of people in different climatic regions. A number of bio-meteorological indices have been developed to describe human thermal comfort level by linking local microclimatic condition and human thermal sensation [Chen and Ng, 2011]. These models are based on the assumption that people's exposure to a climatic environment has, over time, enabled them to reach thermal equilibrium, and they provide numerical solutions to the energy balance equations governing thermoregulation. One of the most widely used indices is the Physiologically Equivalent Temperature (PET). PET is a temperature dimension index measured in degrees Celsius (°C), making its interpretation comprehensible to people without a great deal of knowledge about meteorology [Mayer and Höppe, 1987]. PET is defined as the air temperature at which, in a typical indoor setting, the human energy budget is maintained by the skin temperature, core temperature, and sweat rate equal to those under the conditions to be assessed [Höppe, 1999]. In urban planning, how outdoor thermal conditions influence thermal sensations of people and their behaviour (use of outdoor spaces) is of great interest for designing urban spaces [Tapias and Schmitt, 2014].

In this context, a research project is designed in order to establish the relationship between, microclimate conditions, building geometries and outdoor thermal comfort in Barranquilla, Colombia. This knowledge will be translated into a parameterized design-feedback tool in order to explore 'design spaces' of urban forms [Tapias and Schmitt, 2014].

This paper describes the methodology implemented to acquire local microclimate data with portable weather stations, and explores the first results of the PET calculations.

2. Data acquisition

Barranquilla is known as The Golden Gate of Colombia for being the point of entry of advances such as aviation and phone, of thousands of foreigners and sports like football and baseball. It is also known as 'La Arenosa' because of the amount of sand covering the city due to predominant winds during the year. The city is located in the northeast corner of the department of the Atlantic, on the west bank of the Magdalena River, 7.5 km from its mouth in the Caribbean Sea. The city is sited at latitude 10 ° 59 '16 " North of the equator and longitude 74 ° 47' 20" West of Greenwich, with reference to the Plaza de la Paz, ground zero of the city [www.barranquilla.gov.co]. Barranquilla is a Tropical, arid steppe and savannah climate, and semi-arid type character with a mean temperature is of 27,4 ºC [www.barranquilla.gov.co].

The campus of the *'Universidad del Norte'* is selected as the local case-study area in Barranquilla. The campus is located North of the city and is settled with the same orthogonal urban grid orientation as the city centre. Within this urban area, four outdoor locations are identified for the data acquisition. The selection is based on four different orientations of pedestrian paths on a human scale that differ from orientation. Additionally, one final location on a rooftop is selected in order to acquire general global data from the surrounding. For the acquisition of microclimate measurements, five portable weather stations are installed and collecting data throughout a year.

One portable weather station is installed for each of the preselected pedestrian-scale locations and mounted at 1.2 meters high from the ground. These stations record measures of air temperature, humidity, rain fall, wind direction, wind speed (anemometer), and atmospheric pressure (barometer). For the location on the rooftop, an advanced portable weather station is mounted, which measures the same parameters plus solar radiation (pyranometer).

To be able to monitor the data throughout the year, a wireless system is implemented. For this procedure to work, a constant Internet connection is necessary. Each portable weather station is equipped with a console, which is installed indoors and visualizes the data collected by the sensors. Additionally to the equipment of the weather stations, a Raspberry Pi computer is connected to this console. The computers have the WeeWx weather software installed, which interacts with the weather station to produce graphs, reports, and HTML pages [www.weewx.com]. With Internet connection, the computer sends the collected data to the WeeWx software, which then produces a HTML page on a web server. In this way, it is possible to monitor the weather stations and observe the measurements. Currently, the portable weather stations are mounted and recording microclimate data in each selected location. The data is updated and displayed every 5 minutes on the web server (barranquilla.arch.ethz.ch/station1 - station5) where the WeeWx software shows by real time data and produces daily, weekly and monthly graphs. This system is necessary for monitoring the weather stations throughout the year. The selected location of the weather stations is show in figure 1, where the red dots are the pedestrian-scale locations and the blue dot is the rooftop location.

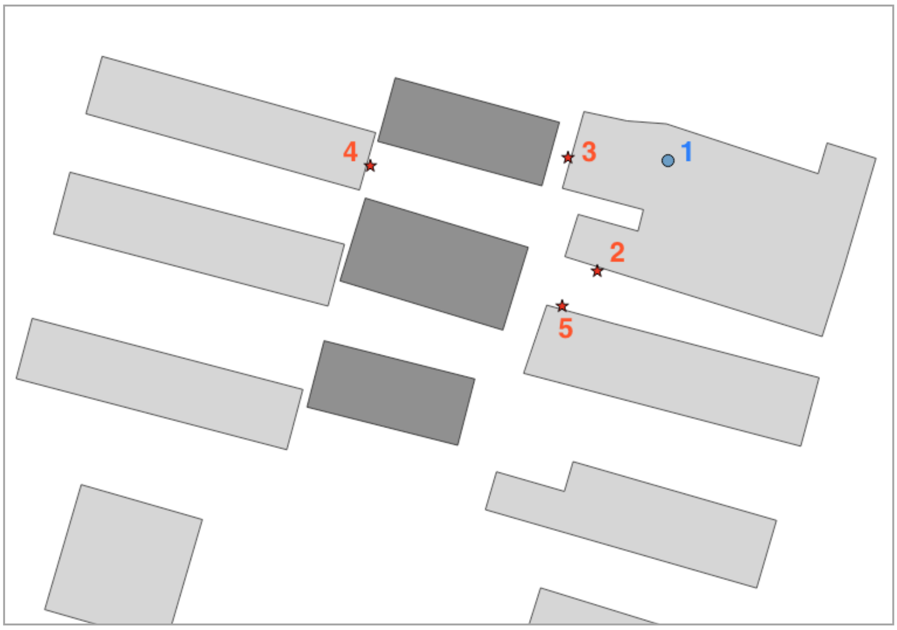


Fig. 1 Location of weather stations (1 – 5). Campus "Universidad del Norte". Barranquilla, Colombia.

3. PET calculations

For the PET calculations, the Rayman model [Matzarakis; Rutz; Mayer, 2007]. From the weather stations, the RayMan model requires data sets of; date (dd.mm.yyyy), time (h:mm:ss), air temperature Ta (°C), relative humidity RH (%), wind velocity v (m/s), and global radiation G (W/m2). The data set of solar radiation obtained from the rooftop station is added into the data set of the other four weather stations (2 – 5), and used as the global radiation input for the PET calculations. For the first calculation of the PET, the month of January 2015 is selected. For this month, the PET of each location varies (table 2) based on their location; the station 2 has the highest values due to its position in the South and longer exposure to the sunlight.

Weather station	PET max. (°C)	PET min. (°C)	PET mean (°C)
2	55.1	18.3	27.1
3	54	17.6	26.6
4	50.7	18.5	25.2
5	51.8	18.2	24.6

Table 1: PET values for each location (2 – 5).

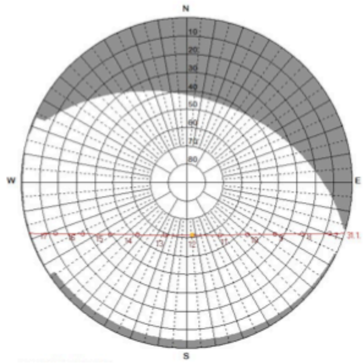
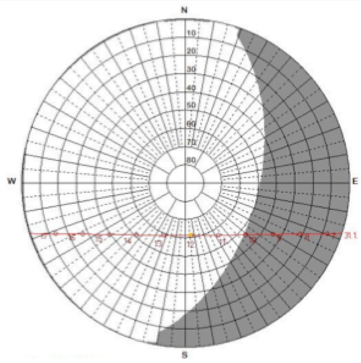
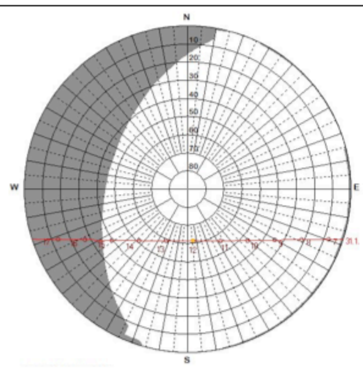
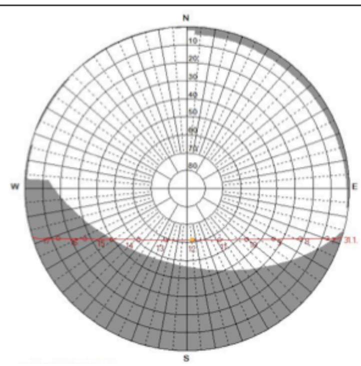
Weather station	Sunpath diagram	SVF
2		0.618
3		0.588
4		0.619
5		0.596

Table 2: Sunpath diagram and SVF during the 31st of January 2015.

Table 2 shows the sunpath diagram and the Sky View Factor (SVF) for each of the locations where the portable weather stations are installed. The sunpath diagrams also illustrate the svf, showing how the buildings in the surrounding area are positioned and affecting the SVF. For this specific situation, the diagrams also show how each of the weather stations are located in opposite orientations according to the urban morphology of the site. In this way, it is possible to compare the four different conditions of the selected urban settlement. It is also important to obtain similar values of the SVF, as the SVF measures the ration of free sky spaces affected by geometry, which is important when correlating 4 locations that only differ on orientation.

To be able to analyse in detail the results, the 31st of January is selected. Figures 2 – 5 show the overlaid of the PET results with the Ta recorded by the portable weather stations. We can see from these graphs how the locations of weather stations 2 and 3 are similar to each other, and the same within the locations of the weather stations 4 and 5. At this point, this statement has no readable explanation and because of this, the procedure has to be conducted for more months of the year, as it has been intended according to the design of the overall research project.

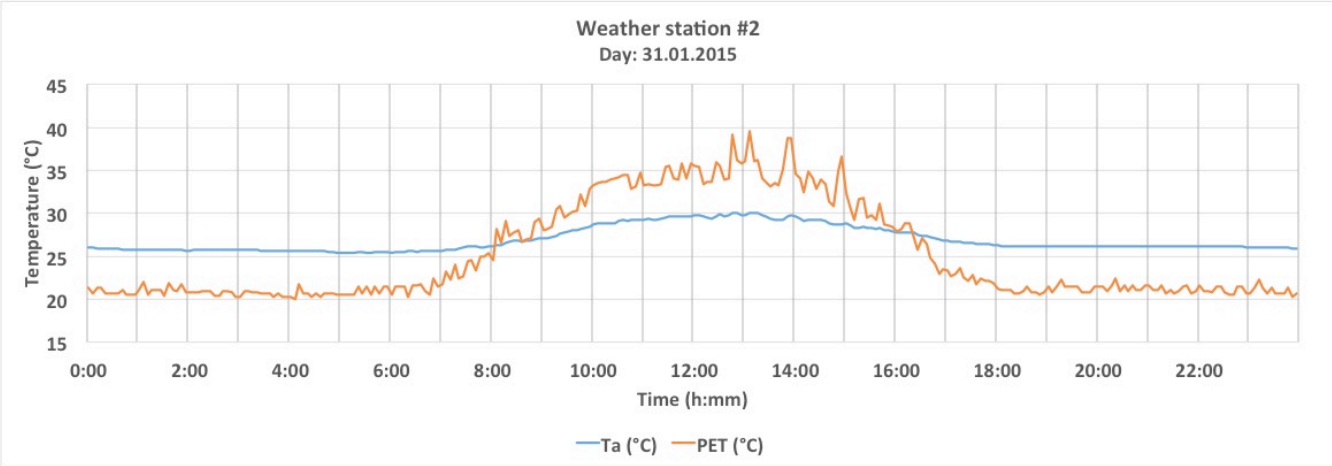


Fig. 2 Ta and PET during the 31st of January 2015. Location of weather station #2

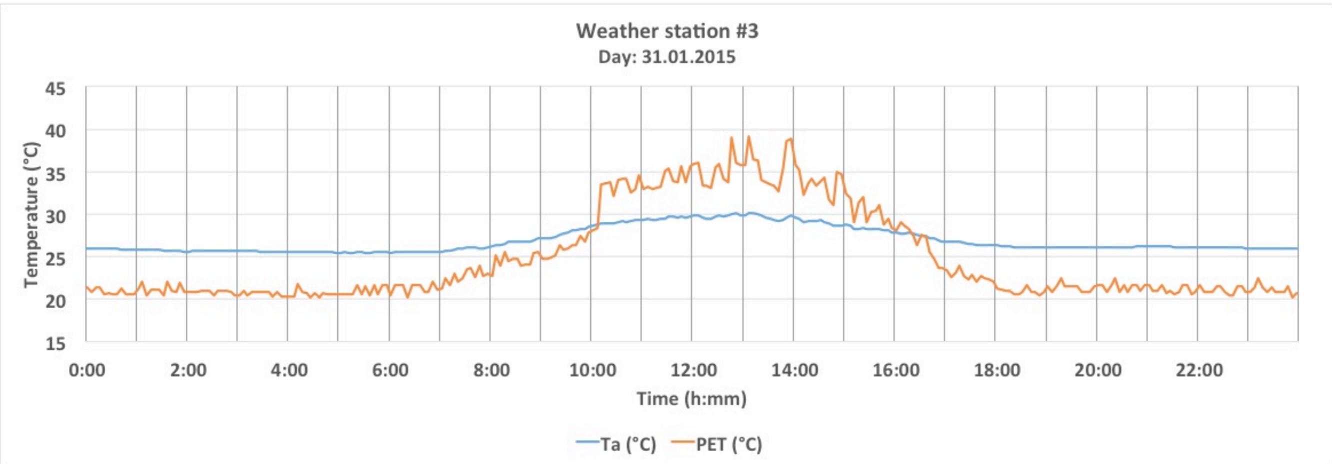


Fig. 3 Ta and PET during the 31st of January 2015. Location of weather station #3

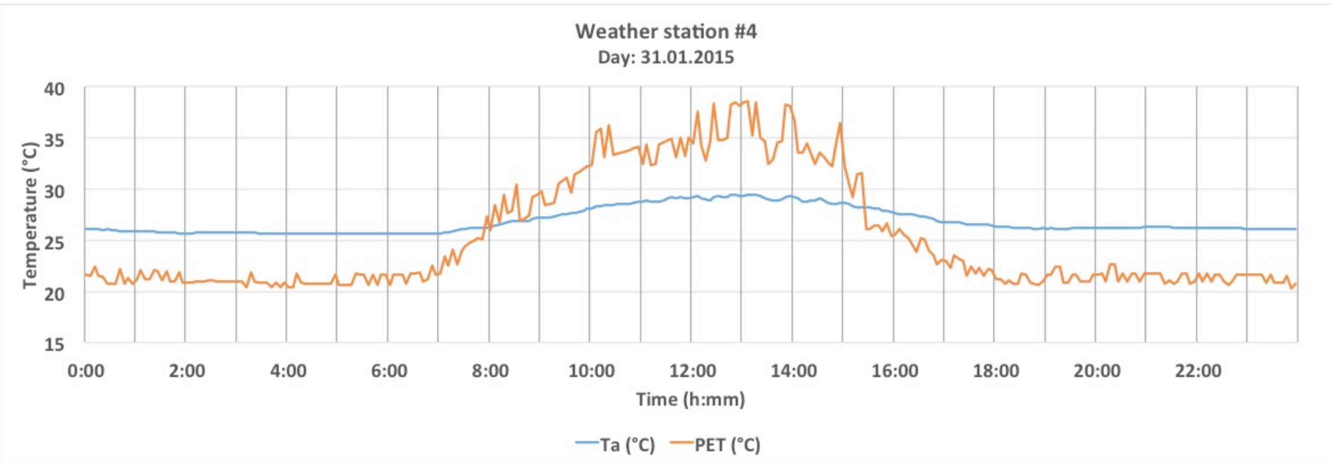


Fig. 4 Ta and PET during the 31st of January 2015. Location of weather station #4

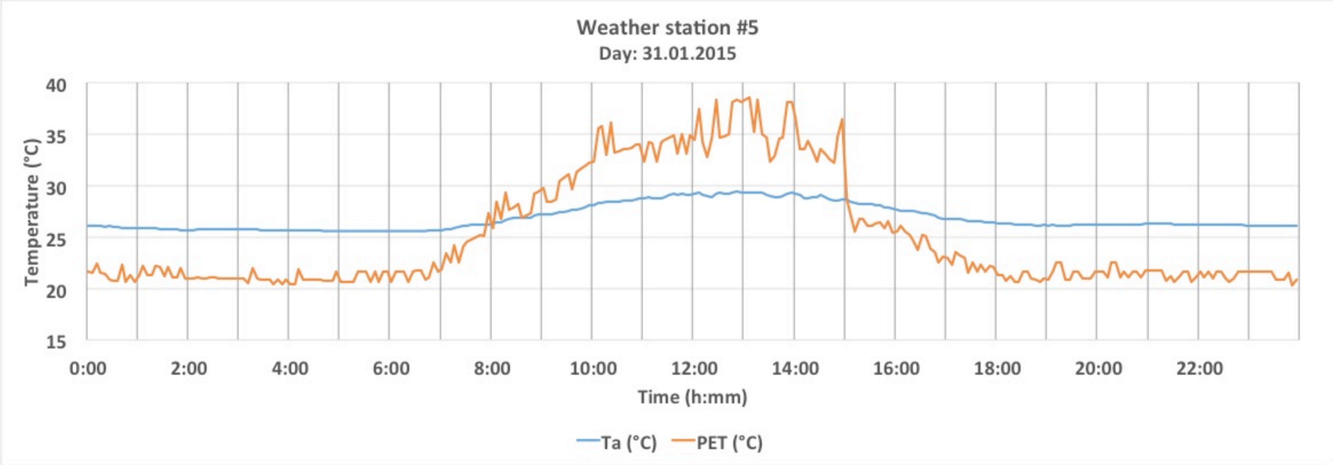


Fig. 5 Ta and PET during the 31st of January 2015. Location of weather station #5

4. Conclusion

The mini portable weather stations are successfully mounted and installed, recording data of different microclimate parameters. The wireless structure enables the long distance monitoring of the measurements of the weather stations. This measurement campaign is intended to last for one year, in order to acquire microclimate data for different weather periods. The first set of results described in this paper show a first insight of what we could predict, such as the fact that the location of the weather station 2 is getting highest values of PET due to its exposure to the South. On the other hand, it s necessary to develop the next set of results with the collection of a long period of data recorded in order to use reasonable amount of data for the final conclusions.

For the second part of the overall research project, a survey campaign on thermal sensation will be executed. With this information it will be possible to correlate the PET calculations of thermal comfort and the actual thermal sensation of people. This information can provide new insights for the understanding of the thermal comfort in Barranquilla, Colombia in order to provide recommendation for urban design and city planning.

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References

Berger, M., 2014: The Unsustainable City. *Sustainability*, ***6*(1),** 365-374.

Chen, L. & Ng, E., 2011: Outdoor thermal comfort and outdoor activities: A review of research in the past decade. *Elsevier: Cities* 29:118–125.

Fröhlich, D., Matzarakis, A., 2013: Thermal bioclimate and urban planning in Freiburg - Examples based on urban spaces. *Theoretical and Applied Climatology* 111, 547-558.

Höppe, P., 1999: The physiological equivalent temperature – a universal index for the biometeorological assessment of the thermal environment. *Int J Biometeorol* 43, 71–75.

Ketterer, C., Matzarakis, A., 2014: Human-biometeorological assessment of adaptation and mitigation measures for replanning in Stuttgart, Germany. *Landscape and Urban Planning* 112, 78-88.

Matzarakis, A., Rutz, F., Mayer, H., 2007: Modelling radiation fluxes in simple and complex environments - application of the RayMan model. *Int J Biometeorol*, 51:323- 334.

Matzarakis, A., Rutz, F., Mayer, H., 2010: Modelling Radiation fluxes in simple and complex environments – Basics of the RayMan model. *International Journal of Biometeorology* 54, 131-139.

Mayer, H. & Höppe, P., 1987: Thermal comfort of man in different urban environments. *Theor. Appl. Climatol*., 38, 43-49.

Tapias, E., Schmitt, G., 2014: Climate-sensitive urban growth: Outdoor thermal comfort as an indicator for the design of urban spaces. *The sustainable city IX : urban regeneration and sustainability. WIT Press.* **1,** 623- 634.

www.barranquilla.gov.co

www.weewx.com