



# Urban climatology in Brazil: An analysis based on the methodology of the urban climate system

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## Abstract

Cities are complex systems, characterized as extremely dynamic organisms, susceptible to the entrance of flows of energy and matter. The growing importance of urban areas in demographic, economic, and cultural terms means that the environmental problems generated by these centers are increasingly a priority for researchers from different areas since such problems can directly affect the quality of life of the people living there. The studies of urban climate are of great importance since they seek to understand atmospheric different dynamics generated by the urban nuclei and their influence on the population of the cities. Therefore, this article, through a bibliographical revision, seeks to briefly present how was structured the methodology of the Urban Climate System, which later became a landmark for the development of urban climatology in Brazil.

**Keywords:** *Brazil, Developing Countries; Local Climate Change; Urban Areas; Urban Climate System; Urban Climatology.*

## Introduction

As human beings advance in the domination and occupation of the territory, primarily as a substrate, building cities, expanding commerce, installing industries and extracting natural resources, that is, when transforming the Earth's surface, it becomes one of the great agents of environment's modification.

Sant'Anna Neto (1995), stated that since *"this environment is 'alive' and regulated by its own processes and dynamics, it responds to the changes imposed by humans, resulting in the most varied levels of derivations of natural and anthropic systems"*. The urban explosion is a global phenomenon, but it is in the underdeveloped countries that infrastructure problems worsen.

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Although it is still an ongoing process, it is found that the world's largest urban agglomerations are growing at an accelerated pace in the underdeveloped countries. Due to the constant degradation of urban environments and their respective effects on the quality of life of the people who live there, the concern with urban management has increased to the researchers and planners of Brazil and the world. In this context, the climatic analysis is highlighted, as it allows the study of several socio-environmental problems, such as changes in precipitation regimes, which can cause serious problems for urban populations. The idea of this article emerged from the publication of the work *"Urban climatology: History, status and prospects"* (Mills, 2014), which describes the evolution of research in urban climatology throughout history, stating in the end that one of the main future challenges is to acquire climate information of cities in less prosperous regions of the world. Considering Brazil as a developing country, it is vitally important to present the efforts that have already been and are being made in the quest for the development of research in urban climatology and in the generation of a reliable database for cities in tropical regions, which can



serve as a reference for research in other parts of the world.

This work aims to summarize the structures and objectives of the Urban Climate System (U.C.S.) methodology proposed by Monteiro in 1976, as well as to present a brief list of some of the most relevant researches in urban climatology carried out later in Brazil, which were influenced and/or have used the U.C.S. as guiding base, to demonstrate the importance that this approach has had and still has for climate analyzes and how this field of research has grown in recent times in a country with serious infrastructure and urban planning deficiencies.

### **Urban landscapes and local climate change**

The process of capitalist production, which gained strength in the nineteenth century, was the main generator of the growing phenomenon of world urbanization, based mainly on industrialization, which generated a rapid increase in productivity and took people from the countryside to the cities. In Brazil, this phenomenon gained visibility between the 1950s and 1960s and has been growing steadily ever since.

Cities are the most radical form of transformation of the natural landscape, because their impacts are not limited to changes in the morphology of the terrain in which they are inserted, but they also modify the environmental and climatic conditions, generating, therefore, an eminently anthropized space, where the intervention of human beings manifests directly or indirectly, being the most significant results the environmental degradation and the generation of a specific climate of urban areas. Aspects such as roughness, buildings, urban geometry and building densification can be decisive indicators in the constitution of the cities' climate, in addition to the economic functions developed, which respond to a certain level of degradation and pollution. Temperature, humidity, and winds are influenced in different ways, but together represent the conditions of existence of an urban climate.

The definition of the urban climate is given in terms of the comparison with its surroundings, and the differences between them. Possibly, the variation in temperature distribution is the most significant change generated by urbanization. This element of city climate impacts on people's performance in their daily activities and also aggravates problems related to environmental quality. The relative

humidity of the air, intimately related to the temperature, is another element of great importance when we deal with urban climate since this increase the thermal sensation perceived by the inhabitants and is directly connected to other elements of the climate.

In addition, in the urbanization process, the removal of the green cover and its replacement by constructed areas raise the albedo index and, consequently, the soil surface retains less amount of energy, increasing the reflectance. It is known that the higher the volume of stored energy, the greater the thermal equilibrium (Conti, 1995). From a theoretical and methodological point of view, the main reference for urban climate studies in Brazil is Monteiro, who in 1976 proposed the U.C.S. based on the General Theory of Systems. The author's proposal is based on the human perception of the urbanized environment, and his results aimed at the planning of the city. The three subsystems of the U.C.S are denominated Thermodynamic, Physical-chemical, and Hydrodynamic. It is an open, adaptive and evolutive system, composed of the local climate and the city.

The Thermodynamic perception channel is related to the thermal comfort of the environment, whereas the Physical-chemical deals with the analysis of the air quality over the city and the Hydrodynamic is related to the meteoric impact, which in the intertropical regions is characterized as concentrated rainfall impact. The urban climate is particular to each urbanized environment. For Monteiro (1990 a, b and c ), the climate of the city can be understood as an open and adaptive system, that when receiving energy from the environment in which it is inserted, modifies it substantially.

Cities are dynamic, that is, they tend to change constantly, widening horizontally and vertically, often provoking new and greater changes in the atmosphere that covers them. In this sense, studies of urban climate are essential, particularly in Brazilian cities still little explored. Even small and medium-sized cities often have characteristics that modify the local climate and are directly linked to the forms of land use. Small and medium-sized cities have very different geographic characteristics from those of large and metropolitan areas, and therefore have considerable facilities for the identification of their intra-urban landscapes; these, previously identified, will allow a better



understanding of the interaction between society and nature in the construction of the urban climate (Mendonca, 1994)

According to Monteiro (1991), *“climate analysis in medium-sized cities becomes easier, and helps to answer questions, as at what point and hierarchical degree a city can provide conditions for the creation of an urban climate”*.

With the urban territorial expansion, the natural environment is modified. To build cities, social agents introduce new equipment and materials in this environment, which causes changes in the local climate. Danni (1987), states that the process of urban growth imposes a particular character on the lower troposphere, thus producing local atmospheric conditions different from those presented in the surrounding areas and giving rise to a particular climate known as the urban climate. As climate is one of the first order elements to compose the geographical landscape, in the cities it is the result of the interaction between the components of the zonal, regional and local atmospheric dynamics and those of the urban-rural (modified) space.

Therefore, the urban climate is derived from the following main changes in the natural environment: the removal of vegetation cover, the introduction of new forms of relief, the concentration of buildings, the concentration of equipment and people, the waterproofing of the soil, channeling of the surface runoff, the roughness of the surface, the launch and accumulating of particles and gases in the atmosphere and the producing artificial energy. (Mendonca, 1994). The factors that control the different processes in the generation of the urban climate are, on the one hand, the characteristics of the regional climate in which the area to be studied is inserted, which imposes the rhythm and temporal distribution of the main climatic elements, and on the other, the factors related to the urban environment, which modify them on a local scale.

The transformations produced by humans in the urban atmosphere affect the energy balance and the water balance. The urban space modifies the albedo since the urban materials have radioactive properties distinct from those found in a non-anthropogenic environment. The intensity and characteristics of these modifications are different depending on the specifics of each urban area, such as the density of buildings, the road network it

presents, the terrain on which it is built, the presence or absence of green areas, among other factors that make each city unique.

By altering the energy balance (albedo), the city produces different rates of heating and cooling compared to the surrounding rural area, generating distinct thermal regimes and causing the formation of the "Heat Island" phenomenon.

*“The heat island or urban thermal island is that the cities are usually, especially at night, warmer than the rural or less urbanized environment that surrounds them. Uniquely, the urban area with higher temperatures usually coincides with the downtown of the cities, where the buildings form a dense and compact set. (...)”*(Garcia, 1991)

According to Oke (1980), even in very small localities, the island's phenomenon of urban heat can occur, and there is no single cause for its formation, but a set of processes that García (1991), summarizes well in his article *“La intensidad de la ‘isla de calor’ de Barcelona. Comparación con otras ciudades españolas.”*

(a) *Increased heat storage during the day in the city, because of the thermal properties of urban building materials and their return to the atmosphere at night.*

(b) *The production of anthropogenic heat (industry, transport, lighting, etc.).*

(c) *The reduction of evaporation, due to the substitution of the original surface for a paved floor and to the efficiency of the urban drainage systems (sewerage, etc.).*

(d) *Less sensible heat loss, due to the reduction of the wind speed originated by the buildings.*

(e) *An increase in the absorption of solar radiation, due to the capture produced by the unique geometry of streets and buildings, which contributes to a relatively low albedo.*

(f) *A decrease in the heat loss during the night by irradiation, also due to the geometric characteristics of streets and buildings that reduce the vision factor of the sky.*

(g) *An increase in the length radiation that is absorbed and re-emitted to the ground by the polluted urban atmosphere.* (Garcia, 1991)

The intensity of the heat island can also vary according to the atmospheric conditions, with the characteristics of the relief and the density of buildings in the study area. Under ideal atmospheric conditions, i.e. in clear sky and calm



wind conditions, the maximum intensity of the heat island occurs. With low relief, the highest temperatures are observed in the most densely built and sparsely vegetated areas. *“Horizontally there is a decrease in temperature as the rural area approaches, characterized by a milder horizontal gradient, this general scheme is interrupted by hot and cold places associated with densities of high and low buildings. (...)”* (Amorim, 2000)

The climate generated by the urban centers provokes effects that are felt more and more by the population, as it generates a thermal discomfort, directly affecting the life of the urban inhabitants.

### The Methodology of the U.C.S

The increase in the urbanization process that occurred in Brazil around the 1950s and 1960s caused a greater concern with environmental

quality and stimulated the first studies on the Urban Climate.

In 1976, Professor Carlos Augusto de Figueiredo Monteiro's “free-teaching” thesis was published, in which the methodology of the U.C.S. was presented for the first time and then applied to the cities of Porto Alegre, Salvador, Rio de Janeiro and São Paulo. Monteiro (1976), constructed the U.C.S. methodology based on the General Theory of Systems, created by Ludwig Von Bertalanffy, associated with Arthur Koestler's holism principle. The paradigmatic choice of the author was due to the fact that this basis would help to reveal the essence of the urban climate since this is a phenomenon of high complexity. In this way, Monteiro established the U.C.S. as a complex, open and adaptive system, that, when receives energy from the larger environment in which it is inserted (solar energy), modifies it substantially (Fig 1).

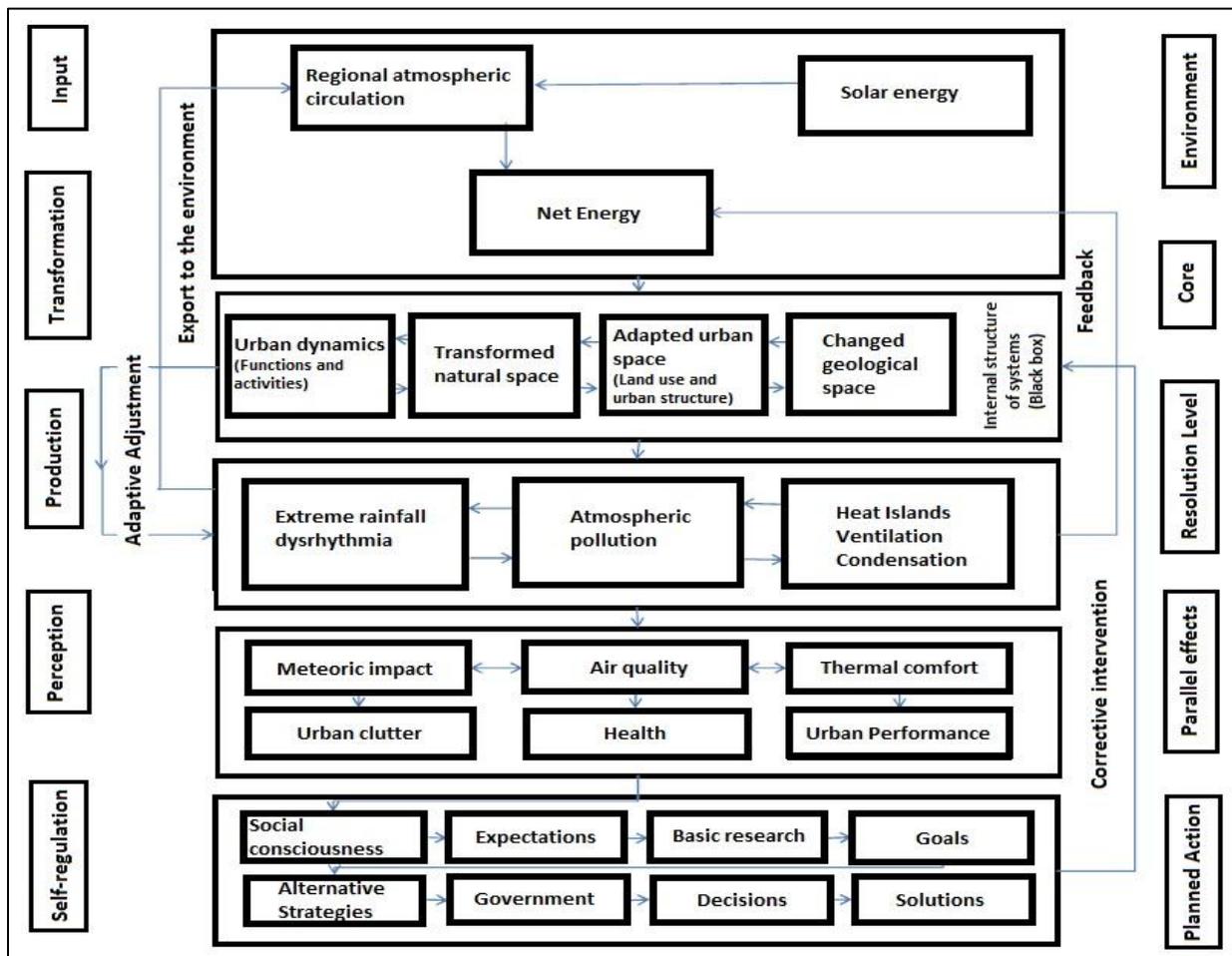


Fig 1. Structure of the U.C.S (Adapted from Monteiro, 1976)



The methodology of U.C.S is projected on the city and its problems, having as a premise the three elements that base the climatology in general: temperature, humidity, and atmospheric pressure. This approach was also innovative in the sense of analyzing the generation of the urban climate through the idea of co-participation between humans and nature and not of the antagonism between them.

*"The internal structure of U.C.S. cannot be defined by the simple superposition or the addition of its parts (ecological, morphological, or functional urban subdivision), but only by means of the intimate connection between them."* (Monteiro, 1976).

Monteiro considers the urban climate as the climate that covers a certain terrestrial space and its urbanization, and the urbanized space constitutes the nucleus of the system. U.C.S. is amenable to self-regulation and is centered on the atmosphere (operator) and humans (operand).

Considering the U.C.S. as an open system, it is necessary to consider, in addition to the factors generating external energy, the internal factors, that is, the human being and the dynamics created by them in the urban space. The U.C.S. also has a result that presupposes elements that characterize the urban participation in the development of the system. Given the complexity of analyzing these elements, it became necessary a classificatory simplification that was expressed through the idea of "human perception channels". The heat islands, air pollution and rainfall are prominent within urban climates, reflecting their peculiarities. The analysis is divided into the perception channels of "Thermal Comfort", "Air Quality" and "Impact Meteors", each connected to a subsystem of U.C.S., which are respectively "Thermodynamic", "Physical-Chemical", and "Hydrometeorologic".

The "Thermal Comfort" channel, linked to the "Thermodynamic" subsystem of the U.C.S., encompasses components derived from heat, ventilation and humidity, while the "Air Quality" channel, linked to the "Physical-Chemical" subsystem, is expressed by atmospheric pollution, which has a very direct association with the different types of weather generating pollution's concentration or dispersion through the air.

The "Meteors of Impact" channel encompasses meteoric forms of precipitation, such as water

forms (rainfall, snow and fog), mechanical (such as tornadoes), and electrical (storms), which may eventually manifest with great intensity and result in large urban impacts, causing disruption to the circulation of people and urban services. In Brazilian cities, the problems arising from the "Hydrometeorologic" subsystem are constant, because of their climatic configuration and the existing socio-environmental problems.

### Researches on urban climatology in Brazil

With the rapid development of studies on the climate of cities around the world, there has also been growing interest among Brazilian researchers in understanding the phenomena generated by urban areas that act as transformers of the local climate. It is not possible to understand the urban climate without inserting it into a larger scale of analysis. *"Urbanized space constitutes the nucleus of a system that maintains close relations with the immediate regional environment in which it is inserted"* (Monteiro, 1976).

The knowledge of the local climate is not sufficient for its complete understanding; it must be related to the regional climate, since it is in this one that the meteorological systems that influence directly the local phenomena take place.

The local climate is embedded in sub-regional and seasonal climates, as well as subdivided into microclimates. The divisions from the systemic point of view are inconsequential, importing predominantly the relations between the different parts in which the system is composed or decomposed for the development of the organizing functions (Monteiro, 1976).

Tarifa (1977), studied the thermo-hygrometric characteristics in the municipality of São José dos Campos / São Paulo, where he compared data collected in rural and urban areas, finding great variations in temperatures, mainly in the daytime period, thus confirming the presence of the heat island on the urban nucleus of the municipality.

Analyzing the Metropolitan Area of São Paulo, Lombardo (1985), also detected a strong presence of urban heat island, especially in the first hours of the night period. In her study, Lombardo took into account, mainly, the environmental quality and the influence of urban growth on it. In 1990 (a, b, c), Monteiro published three articles with the objective of contributing to the urban climate research, in



which he stated that to carry out the study of the urban climate, it is necessary to perform meteorological analysis on the cities, considering them as "geographical facts", defining thus an approach strategy for conducting research. He also stated that it is necessary to know all the aspects related to the city, including the culture of the society that creates them, for a better understanding of its forms of occupation and the activities carried out within it.

In the same year, Monteiro and Sezerino (1990), complementing the studies already done, introduced the concept of "thermal field", based on the analysis carried out in the city of Florianópolis/Santa Catarina, where, with the use of mini shelters equipped with psychrometers installed at fixed points, detected strong differences in temperature in the various schedules analyzed. In 1994, based on his studies in the city of Londrina / Paraná, Mendonça (1994) identified fifteen different "climatic environments". Making collections in the summer and winter months, he detected the presence of strong urban heat islands, with values often higher than 10°C. Sant'Anna Neto (1995), verified a generalized increase of precipitation in several cities of the state of São Paulo, with higher concentrations in the spring/summer, that is, the rainfall increment did not occur uniformly in the different seasons of the year, but, on the contrary, they were higher from October to March. The author also noted that the dry season, which used to be concentrated between April and September, in most of the state, has lasted until October in the last decades.

Pitton (1997), analyzed the strong influence of urban centers on climate and stated that the urban organism is one of the main reflexes of human beings acting on the natural environment. Her research focused on the thermal field since the author considered that it is from this that the climatic characteristics of the city are produced, stating that in the studies of urban climate the systemic approach is necessary and useful. He retakes the idea of Monteiro (1976) that approached the urban climate as "singular system" that includes the natural and the social facts. Amorim (2000), studied the effects of a medium-sized city (Presidente Prudente/São Paulo), located near the Tropic of Capricorn and at a distance of approximately 600km to the ocean. The author

stated that in order to understand the urban climate of the municipality, it was necessary to take into account factors such as the type of land use and occupation, besides considering the importance of the presence of green areas and afforestation on the sidewalks to soften the temperatures and contribute to the moisture balance within the urban core. Through a temporal and spatial analysis of the municipality, Amorim (2000), identified the presence of a urban heat island throughout the day, showing greater magnitudes at dawn and at sunset.

In the year of 2002, Sant'Anna Neto organized a book with studies of some Brazilian cities as São Luís in the state of Maranhão, Aracajú in Sergipe, Campo Grande in Mato Grosso do Sul, Petrópolis in Rio de Janeiro and Sorocaba and Penápolis in São Paulo.

Araújo and Sant'Anna Neto (2002), analyzed the urbanization process and the forms of occupation in the municipality of São Luís/Maranhao, which, even though being a city located close to the equatorial zone, thus receiving more direct insolation, it also suffers changes in the local climate, generated by the forms of land occupation and by the economic activities carried out in the urban center. Pinto (2002), in a study about the local climate of the municipality of Aracajú, capital of the state of Sergipe, stated that the city can be considered privileged by rainfall, when compared to other municipalities in the northeastern territory, because it has a lower variance than others, characteristic of the coastal localities. However, Pinto (2002), stated that the high rainfall does not necessarily imply good chronological distribution and that the municipality also faces difficulties related to rainfall.

In relation to Campo Grande/Mato Grosso do Sul, Anunciação and Sant'AnnaNeto (2002), concluded that the presence of heat and freshness islands do not depend on the season of the year, being present both in summer and winter, periods analyzed in the study. Hack (2002), focused his study on the urban climate in the municipality of Petrópolis, located at 895 meters of altitude, in the state of Rio de Janeiro. The author concluded that due to its high altitude, Petrópolis presents milder temperatures during most of the year, and it was through the climatological analysis from 1931 to 1975 that he could verify that the municipality does not present dry season. In a study about the city of Sorocaba/



São Paulo, Tavares (2002), sought to define climatic patterns resulting from urbanization processes, relating regional, local and urban aspects in his analysis. The author based his studies on the daily differentiation of climatic elements, mainly temperature, analyzing the years of 1987, 1988, 1989 and the first half of 1990.

Silva *et al.* (2002), studied the urban climate of Penápolis/São Paulo in a winter episode, where they could perceive the presence of the heat island phenomenon mainly in the night period, presenting peaks at the time of 21h. Viana (2006), in a study on the urban climate of Teodoro Sampaio/São Paulo, defined seven data collection points that covered districts with very distinct land uses and occupation characteristics, as well as perform transects in the evening between 20h30min. and 21h. As a result, she found a pattern: the densely constructed urban areas, with paving and little vegetation, were more heated and had lower relative humidity than the adjacent ones, which have a lower density of buildings and unpaved streets, and the rural area, which among them was more fresh and humid. Andreoti (2009), compared the microclimate between two buildings in the municipalities of São Paulo and São Roque/ São Paulo, which have great differences due to land use, also related to the population density of each center. The author installed temperature and air humidity meters at the two points, and the collected data were submitted to statistical treatments in order to allow comparison. From these results, the author identified higher temperature values and lower relative humidity in the property located in São Paulo. More recently, Lima (2015), evaluating the Metropolitan Area of São Paulo identified evidence of urbanization effects on rainfall behavior, such as a tendency to increase seasonal and annual rainfall totals and increase the occurrence of episodes with more rainfall (above 20 mm), recorded mainly in meteorological stations located in densely waterproofed areas. Finally, Barros (2016), carried out the evaluation of the urban thermal field of the city of São Paulo and of all the climatic and anthropogenic variables that condition it. The results showed that the conformation and territorial dynamics of the urban heat island corresponded to different synoptic conditions, which determined the transport of moisture from the ocean to the continental atmosphere and, consequently,

transformed the local energy balance. The scenario called attention to the preservation and expansion of vegetation in urban areas since these have proved to be the source of the reduction of the urban surface temperature.

### Final considerations

The urban climate studies are of great importance because they seek to understand the different atmospheric dynamics generated by the urban nuclei and that directly affects the life of the population of the cities. In Brazil, the efforts already made in the understanding of climatic dynamics in urban areas are mainly based on studies in the thermodynamic field and thermal comfort, being carried out by geographers, architects, and meteorologists, in the great majority. In the last decades, it is possible to observe the increase in the number of studies related to the impact of rainfall in cities, considering that these nuclei have increasingly suffered socio-environmental problems related to episodes of concentrated rainfall, intensified by the vulnerability of populations that have occupied areas that are often inadequate for the construction of human settlements. The main objective of the studies on the urban climate is the search of alternatives for intervention in the environment, aiming at best planning in the construction of the cities so that a better balance between human beings and climatic variables would be possible. It is sad to note, however, that, in general, Brazilian public managers do not yet incorporate climate information as a key element in urban management plans.

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### References

- Amorim, M. C. C. T. 2000. O clima urbano de presidente prudente/ sp. Doctoral thesis. Faculdade de filosofia, letras e ciências humanas, universidade de são paulo.



- Andreoti, C. E. 2009. Comparação microclimática entre dois imóveis nos municípios de são paulo e são roque. *Revista geográfica acadêmica*, 3 (2): 44 – 56.
- Barros, H. R. 2016. A relação entre ilha de calor urbana, o uso e cobertura do solo e o balanço de energia no município de são paulo: avaliação do campo térmico nos parques públicos de lazer. Doctoral thesis. Faculdade de filosofia, letras e ciências humanas, universidade de são paulo.
- Conti, J. B. 1995. Desertificação nos trópicos. Proposta de metodologia de estudo aplicada ao nordeste brasileiro. Habilitation thesis. Departamento de geografia, faculdade de filosofia letras e ciências humanas, universidade de são paulo.
- Danni, I. M. 1987. Aspectos temporo-espaciais da temperatura e umidade relativa de porto alegre em janeiro de 1982: contribuição ao estudo do clima urbano. Master thesis. Faculdade de filosofia, letras e ciências humanas, universidade de são paulo.
- García, M.C. M. 1990. La cartografía del fenómeno de la “isla de calor”. *Notes de geografia física*, 19: 73 – 81.
- García, M.C. M. 1991. La intensidad de la “isla de calor” de barcelona. Comparación con otras ciudades españolas. *Alisios revista de geografia*, 1: 47-53.
- García, M.C. M. 1991. Unas notas históricas acerca de la climatología urbana. *Notes de geografia física*, 20(21): 137 – 14.
- Lima, G. N. 2015. O desafio da manutenção do abastecimento hídrico na região metropolitana de são paulo: busca por uma gestão sustentável .doctoral thesis. Faculdade de filosofia, letras e ciências humanas, universidade de são paulo.
- Lombardo, M. A. 1985. Ilha de calor nas metrópoles: o exemplo de são paulo. *Hucitec*, 244.
- Mendonça, F. A. 1994. O clima e o planejamento urbano de cidades de porte médio e pequeno: proposição metodológica para estudo e aplicação à cidade de londrina, pr. Doctoral thesis. Faculdade de filosofia, letras e ciências humanas, universidade de são paulo.
- Mills, G. 2014. Urban climatology: history, status and prospects. *Urban climate*, 10: 479 – 489.
- Monteiro, C. A. F. 1976. Teoria e clima urbano. Igeog/usp, 181pp. *série teses e monografias*, 25.
- Monteiro, C. A. F. 1976. O clima e a organização do espaço no estado de são paulo: problemas e perspectivas.igog/usp, 54pp. (série teses e monografias).
- Monteiro, C. A. F. 1990 a. Por um suporte teórico e prático para estimular estudos geográficos do clima urbano no brasil. *Geosul*, 5 (9): 7-19.
- Monteiro, C. A. F. 1990 b. Adentrar a cidade para tomar-lhe a temperatura. *Geosul*, 5 (9): 61-79.
- Monteiro, C. A.F. 1990 c. A cidade como processo derivador ambiental e estrutura geradora de um “clima urbano”. *Geosul*, 5 (9): 80 - 114.
- Monteiro, C. A. F. and Sezerino, M. L. 1990. O campo térmico na cidade de florianópolis: *primeiros experimentos.geosul*, 5 (9): 115 - 130.
- Monteiro, C. A. F. 1991. Clima e excepcionalismo: conjecturas sobre o desempenho da atmosfera como fenômeno geográfico.ed. Da ufsc, 241.
- Pitton, S. E. C. 1997. As cidades como indicadores de alterações térmicas. Doctoral thesis. Faculdade de filosofia, letras e ciências humanas, universidade de são paulo.
- Sant’anna neto, J. L. 1995. As chuvas no estado de são paulo. Doctoral thesis. Faculdade de filosofia, letras e ciências humanas, universidade de são paulo.
- Sant’anna neto, J. L. (org) 2002. Os climas das cidades brasileiras. *Unesp*, 227.
- Tarifa, J. R. 1977. Análise comparativa da temperatura e umidade na área urbana e rural de são josé dos campos (sp). *Geografia*, 2(4): 59 – 80.
- Viana, S. S. M. 2006. Caracterização do clima urbano em teodoro sampaio/ sp. Presidente prudente. Master thesis. Faculdade de ciências e tecnologia, universidade estadual paulista “júlio de mesquita filho”.

