510: PROJECT MICROCITIES BRAZIL

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Abstract

The project MICROCITIES Brazil aims to characterize the micrometeorological features of urban climate of two major urban areas of Brazil: The metropolitan regions of São Paulo and Rio de Janeiro Cities. Observations indicated that the UHI is a daytime feature of the local climate in both regions, with a maximum intensity between 2 and 6^{o} C, but occurring early in Rio de Janeiro, between 08:00 and 10:00 Local Time, and latter in São Paulo, between 14:00 and 17:00 Local Time. Observations indicated that UHI in both regions are strongly modulated by the net solar radiation at the surface and sea breeze circulation system. In this work, project MICROCITIES BRAZIL will be described. In this work special attention will be given to the methodology used to estimate the main components of surface energy budget and to characterize the seasonal evolution of the urban boundary layer in these two metropolitan regions. Besides, the major features of the urban climate of both regions are reviewed considering as reference the available literature and in situ observations.

Keywords: energy balance, megacities, Brazil

1. Introduction

The investigation of urban heat island and other urban effects on the climate of cities located at tropical and subtropical areas have received less attention than in other latitudes, as result much less is known about urban climate in these regions.

In the case of Brazil, where the urban fraction of its population is expected to grow from the current 85% (Fig.1) to more than 90% in the next 20 years, the paucity of information is particularly critical.

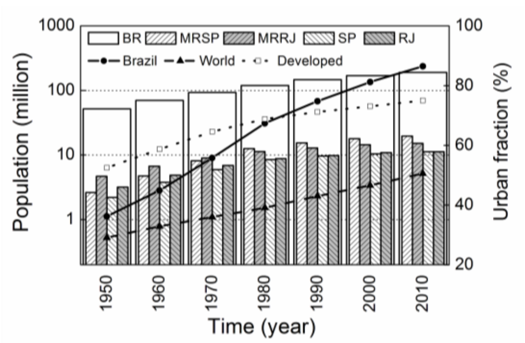

Fig 1. Evolution of the urban fraction of population of Brazil, world and developed countries. Evolution of the population of São Paulo and Rio de Janeiro Cities (SP,RJ) and their respective metropolitan regions (MRSP,MRRJ).

As consequence of this unprecedented population growth, most of the urban areas in Brazil will continue to demand enormous amount of resources to alleviate the shortages of basic social services, lack of infrastructure and chronic air and water pollution problems. Besides, if the IPCC scenarios are confirmed for the region a significant fraction of the population living in large conurbations of Brazil are more likely to become exposure to the adverse effects of climate change, aggravating the need for investment. Moreover, most of the actions taken to modify this condition so far have not been as effective as expected because they are based polices that are not strongly supported by scientific knowledge. The Project MICROCITIES Brazil was designed to assess the main features of the urban climate of the major Brazilian cities and to systematize the procedure of investigation to be easily extended to other urban areas. The major focus of this project is to estimate the observationally the major components of the energy budget at the surface and the dynamic and thermodynamic properties of the urban boundary layer over urban areas of Brazil.

The metropolitan regions of São Paulo and Rio de Janeiro Cities (MRSP, MRRJ) were chosen as the starting point in this project because they are the largest conurbations of Brazil. Altogether, they occupy approximately 13,733 km^2 with a population of 31.6 million inhabitants and a fleet of 10.6 million vehicles (Table 1). These two metropolitan areas contribute to almost 45% of the Brazilian gross domestic product (BGPD). The cities of São Paulo and Rio de Janeiro became megacities in the 1990s and 2000s respectively. Besides the social and economical importance, these two metropolitan regions are likely to be contributing to climate change as major sources of green house gas (GHG). According to [1] the emissions per capita for São Paulo and Rio de Janeiro Cities correspond respectively to 18.3 and 28.0 % of the national emissions estimated as 8.2 tons of CO_2 equivalent per capita. Most of urban emissions in Brazil are due to transportation although at national level GHG emissions are due basically to the rural activities (deforestation and cattle).

Table 1: Major social and economical features of the metropolitan regions of São Paulo and Rio de Janeiro.

Features	RMSP	RMRJ
Number of cities	38	20
Area (km^2)	8.051	5.682
Population	19.672.582	11.875.063
Number of vehicles	6.900.000	3.630.678
BGPD´s fraction	33,92%	11,15%

2. Project description

Project MICROCITIES Brazil aims to describe observationally the major urban climate features of MRRJ and MRSP. In this initial phase there will be set up four micrometeorological towers. Two of these towers (TU1 and TU3) will be located at the top of the buildings located in the University of São Paulo and Federal University of Rio de Janeiro campus (Fig. 2 and 3).

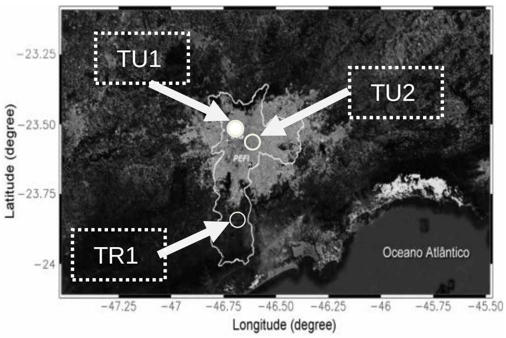

Fig 2. Location of the micrometeorological towers TU1, TU2 and TR1 in the City of São Paulo. The existing tower TU1 is indicated by solid circle. The other towers (TU2, TR1) are indicated by circle. The administrative area of São Paulo is indicated by white line.

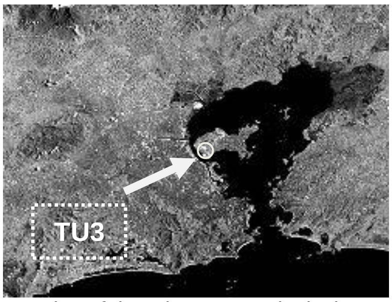

Fig 3. Location of the Micrometeorological towers TU3 in the City of Rio de Janeiro.

These areas are characterized by a suburban type of land use (Fig. 4 and 5). In the case of São Paulo City, it will be set up two new micrometeorological towers (TU2 and TR1 in Fig. 2). Tower TU2 will be set up in the densely built area and tower TR1 in the rural area located South of São Paulo City (Fig. 1).

Fig 4. Landuse in the area around the micrometeorological tower (TU1) existing in the top of the IAG building in the City of São Paulo. White circle has radius of 1 km.

Fig 5. Landuse in area around the micrometeorological tower (TU3) to be set up in the top of the Institute of Geosciences building (IGEO) located in the Campus of the Federal University of Rio de Janeiro, Fundao Island, Rio de Janeiro. White circle has radius of 1 km.

Fig 6. Micrometeorological tower (TU1) in the top of Institute of Astronomy, Geophysics and Atmospheric Sciences 4-store building (IAG) located in the Campus of the University of São Paulo, São Paulo.

All four micrometeorological towers will be set up with a set of sonic anemometer and infrared gas analyser at 10 meters above the surface. This fast response sensors will be measuring the three components of wind speed, water vapour and carbon dioxide concentration with sample rate of 10 Hz. A net radiometer will provide continuous measurement of net radiation at 5 meters above the surface. In the urban sites (TU1, TU2 and TU3) surface is the top of the building (Fig. 6).

The surface In the rural site is the ground level. All four towers will also measure conventional meteorological parameters (wind speed and direction, temperature and relative humidity, atmospheric pressure, and rain). In the urban sites the surface temperature will be estimated using a infrared sensor, while in rural site the soil heat flux and temperature will be estimated using placing a heat flux and temperature sensor at 5 cm below the surface.

To take into consideration the effects of the complex topography and heterogeneous land use of the urban sites on the turbulent fluxes measurements a detail analysis of the landuse and topography of the area within 1 km of radius has been undertaken based on objective analyses of orthophotos and Landsat images. In this analysis the categorical classification of building characteristics (14 building parameters) proposed in the National Building Statistics Database [2] is adapted these two cities taking into consideration the available information and field work.

Besides the major components of the energy balance at the surface, the Project MICROCITIES Brazil will also carry out two field campaigns: one in the summer (February) and other in the winter (August) in 2013. Each campaign will last 10 days and radiosonde soundings will provide high resolution vertical profiles of temperature, relative humidity, wind speed and direction, every 3 hours in the Airport of *Campo de Marte* in São Paulo and Airport of *Galeão* in the Rio de Janeiro. Simultaneously, during the observational campaign two lidars from IPEN [3] will provide high temporal resolution information of the mixing layer thickness in both cities. An example of daytime evolution of the mixing layer tickness in São Paulo City yielded by lidar one of IPEN´s lidar is given in the Fig. 7. There, the mixing layer is indicated by the bright colours and may be extended at the end of the day up to 1300 meters above the surface.

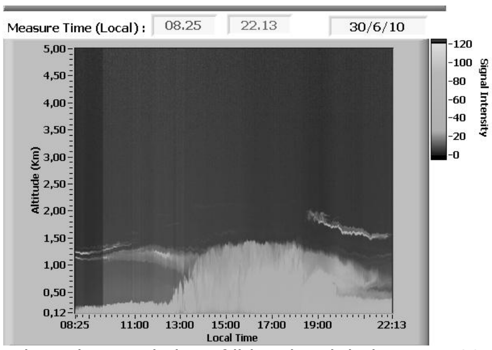

Fig 7.Time evolution of lidar signal during June 30, 2010. The lidar was set up in the Institute of Nuclear Energy Research (IPEN) located in the campus of the University of São Paulo, São Paulo.

3. Urban features

The city of São Paulo (23°33'1"S, 46°38'2"W) is part of a conurbation of 39 cities that composed the MRSP, situated about 60 km from the Atlantic Ocean. It is located approximately 700 m above mean sea level with a surface of about 1508 km² and population estimated near 11 million inhabitants.

According to [4] the climate of São Paulo is typical of the subtropical regions of Brazil, being characterized by a dry winter from June to August, and a wet summer from December to February. The smallest daily values of temperature and relative humidity occur in July and August (16°C and 74% respectively), and the lowest monthly accumulated precipitation occurs in August (30 mm). The largest daily value of temperature and monthly accumulated precipitation occurs in February (22.5°C and 255 mm), while the maximum relative humidity (80%) is observed in two periods: December-January and March-April.

The patterns of circulation in the city of São Paulo indicate a predominance of northeasterly flow, with velocities at the surface varying from 1.5 to 2.0 m s^{-1} during night time and in the morning. The winds are associated with the semi-stationary subtropical Atlantic high pressure system (South Atlantic High). During the afternoon and early night, the sea breeze penetrates the MRSP, shifting the wind direction to southeasterly and increasing the surface wind velocity to 2.5 to 3.0 m s^{-1}. The large scale pattern is frequently disturbed by the passage of cold fronts. The topography and land use also affect the wind in the MRSP. Blocking caused by buildings and channelling in canyons and valleys are the dominant effects when the winds are strong. When the winds are weak (<2 ms^{-1}), the thermal circulation induced by mountain valley circulation plays a strong role in the local circulation. The low level circulations induced by the urban heat island have not been detected observationally in São Paulo [5]. Continuous observations of all components of radiation balance carried out ant the surface since 2004 indicated that in the City of São Paulo the monthly average values of atmospheric broadband transmissivity vary from 0.36 to 0.57, effective surface albedo from 0.08 to 0.10, atmospheric effective emissivity from 0.79 to 0.92 and surface effective emissivity remains approximately constant and equal to 0.96 [6].

The major climate features of RMRJ are basically similar to the RMSP. The city of Rio de Janeiro is characterized by a dry winter (June-August) and wet summer (December-February). In average the wind near to the surface are low (< 3 ms^{-1}) and strongly modulated by sea breeze circulation that penetrates regularly much early than in São Paulo [7].

According to [4] the impact of anthropogenic heat on the local climate is not important because the maxima amplitude of the diurnal evolution is around 20 Wm^{-2} and the daily value (integrated during 24 hours) represents about 9% of the net radiation in the summer and 15 % in the winter. It should be emphasised that approximately 50% of the anthropogenic heat in the city of São Paulo is produced by the vehicular emission of heat caused by fleet of about 3.5 million vehicles circulating daily. Unfortunately there is no information available about the anthropogenic heat in the RMRJ.

The urban heat island intensity was evaluated for the MRSP and MRRJ as the difference between the mean air temperatures (observed at screen level) over the urban area minus the mean air temperature over the non urban (vegetated) area. In the case of São Paulo (Fig. 8) the stations 1-6 are urban and stations 7-13 are rural landuse [6], In the case of Rio de Janeiro (Fig. 9), stations 1 (Donwtown) and 2 (Fundão Island) are urban and stations 5-8 are vegetated landuse [7].

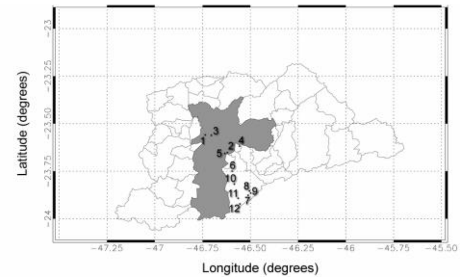

Fig 8. Spatial distribution of surface stations in MRSP used to estimate the UHI intensity.

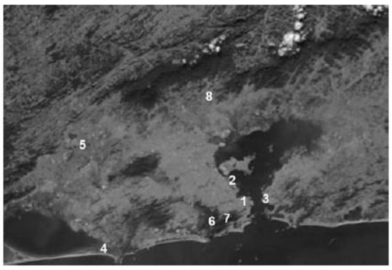

Fig 9. Spatial distribution of surface stations in MRRJ used to estimate the UHI intensity.

The seasonal variation of the diurnal evolution of the UHI intensity of São Paulo and Rio de Janeiro are indicated in the Figs. 10 and 11. The UHI in is, both regions, a daytime feature of the local climate with a maximum intensity between 2 and 6^{o} C. It occurs early in Rio de Janeiro, between 08:00 and 10:00 Local Time, and latter in São Paulo, between 14:00 and 17:00 Local Time. This observations indicated that UHI in both regions are strongly modulated by the net solar radiation at the surface and sea breeze circulation system.

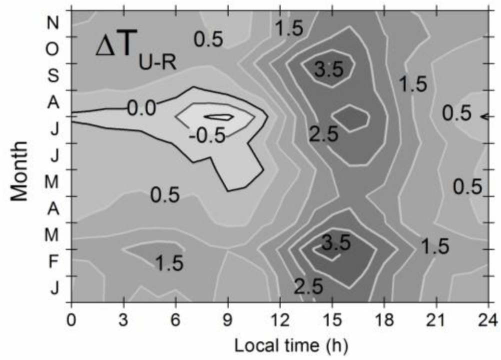

Fig 10. Urban Heat Island in São Paulo City [6].

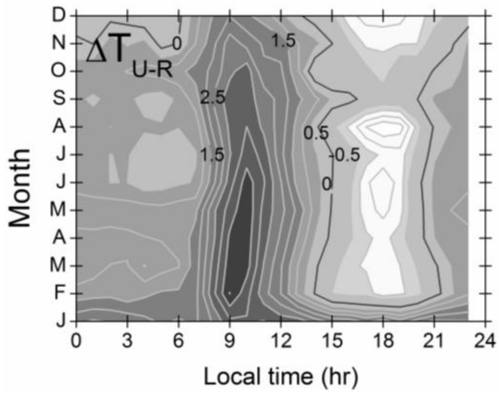

Fig 11. Urban Heat Island in Rio de Janeiro City [7].

4. Conclusion

The project MICROCITIES Brazil main goal is to estimate observationally the major components of the energy balance at the surface in the metropolitan regions of São Paulo and Rio de Janeiro Cities. Observations indicated that the UHI in both metropolitan regions are a daytime feature of the local climate modulated by sea breeze circulation and net solar radiation at the surface.

5. Acknowledgements

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