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PROGRAM MCITY BRAZIL

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1. Introduction

The Program *MCITY BRAZIL* was designed to assess the urban effects on the 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 program is to estimate the observationally the major components of the surface energy budget (SEB) and associate them to the dynamic and thermodynamic properties of the urban boundary layer. The metropolitan regions of São Paulo and Rio de Janeiro Cities (MRSP, MRRJ) were chosen as the starting point because they are the largest conurbations of Brazil. They are located at similar subtropical zone (Fig. 1) and altogether occupy approximately 13,733 km^2 with a population of 31.6 million inhabitants and a fleet of 10.6 million vehicles (Table 1).

Table 1: Major social and economical features of the metropolitan regions of São Paulo and Rio de Janeiro (IBGE, 2010).

Features	MRSP	MRRJ
Number of cities	39	19
Area (km^2)	8,051	5,682
Population	19,672.582	11,835,708
Number of vehicles	6,390,092	3,630,678

Figure 1. Geographic localization of the Metropolitan Regions of São Paulo and Rio de Janeiro Cities.

2. Implementation

The MCITY BRAZIL Program begins in 2012 with the incorporation of turbulence measurements system of the micrometeorological platform in the MRSP (PM IAG) and the implementation of 2 new platforms (PM ITU and PM SFZ) in the MRSP and 1 new platform (PM IGEO) in the MRRJ in 2013.

Measurements in the PM IAG is carried out with a 10 tower located at platform the top of 4-store building in the University of São Paulo campus respectively at 17 m above the surface (Fig. 3). In the PM ITU a 10 m tower was set up at the surface level in the rural region located at south of MRSP, Itutinga Pilões State Park reserve area, characterized by reforestation area of Atlantic Forest (Fig. 4). In the PM SFZ a 10-m tower was set up at the top of 18-store building in down town São Paulo City, about 77 m above the surface, in an area predominantly urban (Fig. 5). In the PM IGEO the 10-m tower was set up at the top of a 3-store building in the University of Rio de

Janeiro campus, located in the Fundão Island (Fig. 6). In the MRSP all 3 platforms are located at similar altitudes varying from 741 m to 760 m above the mean sea level whereas in the MRRJ is the platform is located at the sea level (Table 2).

(a) MRSP

(b) MRRJ

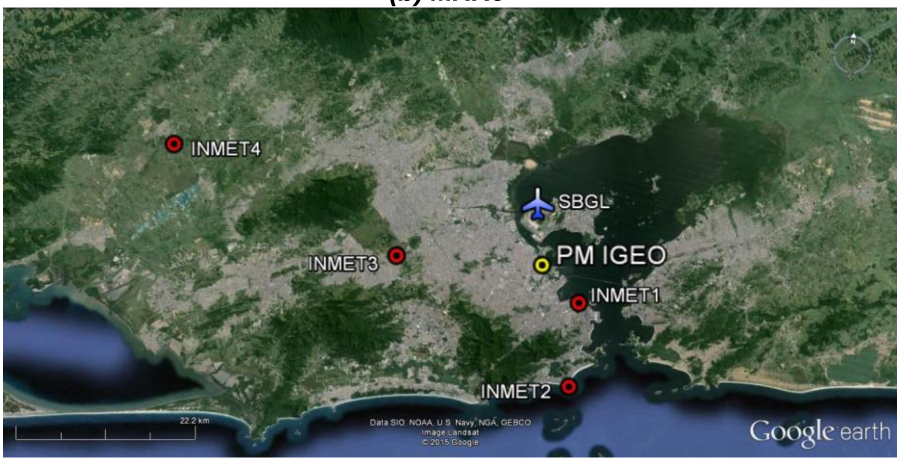


***Figure 2**. Geographic position of (a) PM IAG, PM SFZ and PM ITU in MRSP and (b) PM IGEO in the MRRJ. Campo de Marte (Marte) and Galeão Airports(SBGL) are indicated by airplane symbols. Climatological stations are indicated by Mirante and PEFI in São Paulo and by INMET 1-4 in Rio de Janeiro.*

Table 2. Geographic features of the micrometeorological platforms, airports in São Paulo and Rio de Janeiro.

Metropolitan Region of São Paulo					
Site	landuse	Height (m)*	Latitude	Longitude	Altitude (m)**
PM IAG	Suburban	17	23º 33' 34" S	46º 44' 01" W	744
PM ITU	Rural	0	23° 49' 32" S	46° 30' 32" W	760
PM SFZ	Urban	77	23 33' 01" S	46 37' 49" W	741
MARTE	Suburban	0	23º 30' 32" S	46º 38' 04" W	722
Metropolitan Region of Rio de Janeiro					
Site	landuse	Height (m)*	Latitude	Longitude	Altitude (m)**
PM IGEO	Suburban	12.5	22° 51' 26" S	43° 14' 01" W	10
GALEÃO	Suburban	0	22° 48' 32" S	43° 14' 59" W	10
* Above the surface. ** Above mean sea level.					

Besides surface measurements during 2013 four field campaigns were carried where measurements of vertical profiles of temperature, relative humidity, wind speed and direction using radiosonde released every three hours during 10 consecutive days in Summer and Winter seasons in São Paulo (February 19-28 and August 6-15, respectively) and in Rio de Janeiro (March 12-21 and July 9-19, respectively). In São Paulo the radiosondes were released at the Campo de Marte Airport and in Rio de Janeiro at the Galeão Airport (Marte and SBGL in Fig. 2). During these campaigns a LIDAR monitored the vertical extent of the Planetary Boundary Layer (PBL) at the University of São Paulo campus (about 1 km far from PM IAG) in São Paulo City and at the University of Rio de Janeiro campus (in the PM IGEO) in the Rio de Janeiro City (Fig. 2).

3. Results and Conclusion

Turbulent fluxes of sensible and latent heat are estimated considering the eddy-covariance method. Sonic anemometer provides times series of the 3 components of wind velocity (u, v, w) and air temperature (T) with a sample frequency of 10 Hz. Similarly, a gas analyzer provides simultaneous times series of water vapor density (ρ_{H20}) and carbon dioxide concentrations (ρ_{CO2}). Neglecting periods when the meteorological variables are not statistically stationary in this work turbulent fluxes sensible, latent, CO2 and friction velocity are estimated for 30 minutes intervals following relations: $H = \rho\, c_P \overline{(T'w')}$, $LE = L_V\, \overline{(\rho'_{H20} w')}$, $F_{CO2} = \overline{(\rho'_{CO2} w')}$ and $u_* = \sqrt[4]{\overline{(u'w')}^2 + \overline{(u'w')}^2}$, ρ is the air density, c_p is the specific heat of air at constant pressure and L_V is the water vapor latent heat. Turbulent fluxes of latent and carbon dioxide are estimated considering the effect of density fluctuations and non-zero vertical velocity at the surface effects known as Webb correction (Aubinet et al., 2010).

(a) PM IAG: 10 m tower ***(b) PM IAG: 4 store building***

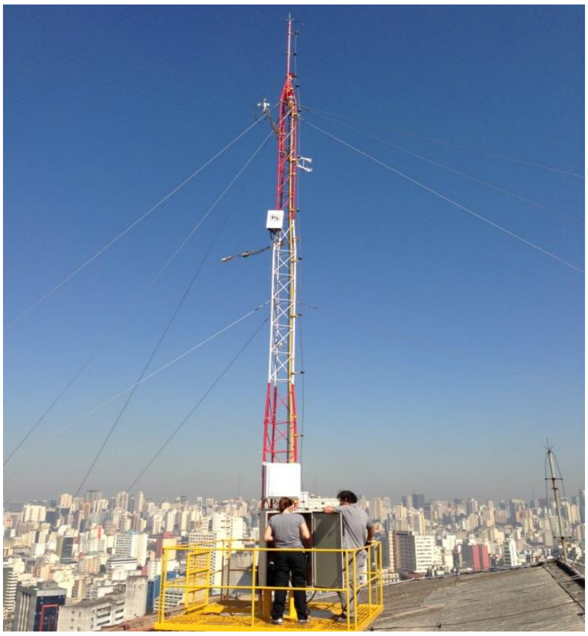
Figure 3 *Micrometeorological platform of IAG (PM IAG) located in the top of 4th store building at the University of São Paulo Campus at West of São Paulo City: (a) 10-m tower, (b) 4-store building.*

(a) PM ITU: 10 m tower ***(b) PM ITU: Surface sensors***

Figure 4. *Micrometeorological platform of Itutinga Pilões (PM ITU) located in the Atlantic Forest area in the vicinity of São Paulo City: (a) 10-m tower, (b) surface sensors.*

The diurnal evolution of H, LE, F_{CO2} and u_* are indicate for the MRSP and MRRJ in the Figures 7 and 8. They correspond to covariance estimated over 30-minutes intervals during the 1st and 2nd campaigns carried out in the MRSP (February) and MRRJ (March). Table 3 displays the daily values of H and LE estimated by integrating the mean values of the entire 10 days of each of the four field campaigns. Bowen ratio indicated in Table 3 shows that the PM IAG has a more urban character with higher H and smaller LE than in the PM IGEO (Fig. 7a-b, Fig. 8a-b). Friction velocity has a similar amplitude indicating that the exchange of momentum are comparable in both sites. During the Summer campaigns vegetation plays an important role in the diurnal evolution of CO2 flux, acting as CO2 sink during daytime and CO2 source during nighttime in both sites (Figs. 7d and 8d).

(a) PM SFZ: 10-m tower



(b) PM SFZ: 18-store building

Figure 5: *Micrometeorological platform of Secretaria da Fazenda (PM SFZ) located in the top of a 18-store building downtown São Paulo City: (a) 10-m tower, (b) 18 store building.*

(a) PM IGEO: 10 m tower

(b)PM IGEO: 3-store building

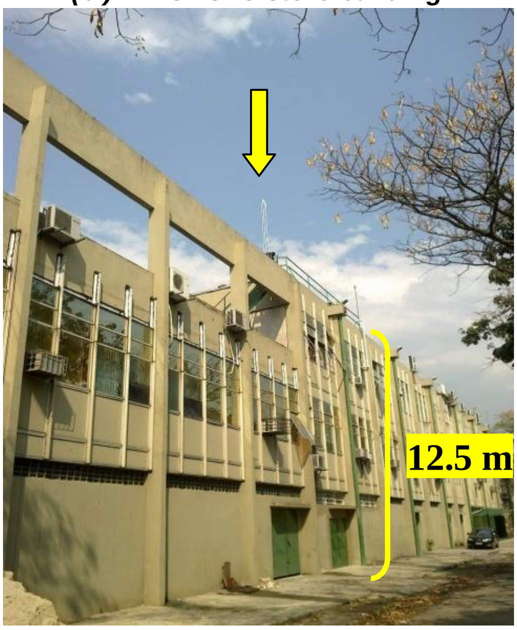


Figure 6. *Micrometeorological platform of IGEO (PM IGEO) located in the top of a 3-store building at the University of Rio de Janeiro Campus at Fundão Island: (a) 10-m tower, (b) 3-store building .*

The time evolution of PBL height estimated for each 3-hours radiosounding during 1st (Summer) and 4th (Winter) campaigns of MCITY BRAZIL in the MRSP. Fig. 9 displays diurnal evolution observed in MRSP during February 20, 2013 (Summer) and August 8, 2013 (Winter). The PBL height was estimated considering visual inspection of vertical profiles of potential temperature and specific humidity and alternatively, using Richardson number (RI) criteria. Best results, using visual inspection as reference, was obtained for RI =1.46. There is a good agreement also with estimated based on LIDAR.

Numerical simulations carried out by WRF (version 3.0) were carried out during 1st campaign show a good agreement with observations in the RMSP. In these simulations were used 2 horizontal domains both centered in Campo de Marte Airport (Fig. 3a), representing areas of 1500 km x 1500 km (100 x 100 grid points) and 485 km x 485 km(97 x 97 grid points). In the simulations described here, it was used landuse classification provided by United State Geological Survey (USGS). Topography in the domains area were composed from GTOP30 files available at (NOAA, 2014). The temperature and humidity fields in the first 4000 meters during 10 days period in the August of 2013 were very well simulated by the WRF (Fig. 10). This indicates that despite the simplified representation of landuse, mainly in the urban area of MRSP, all major features of local atmosphere was very well represented by the WRF.

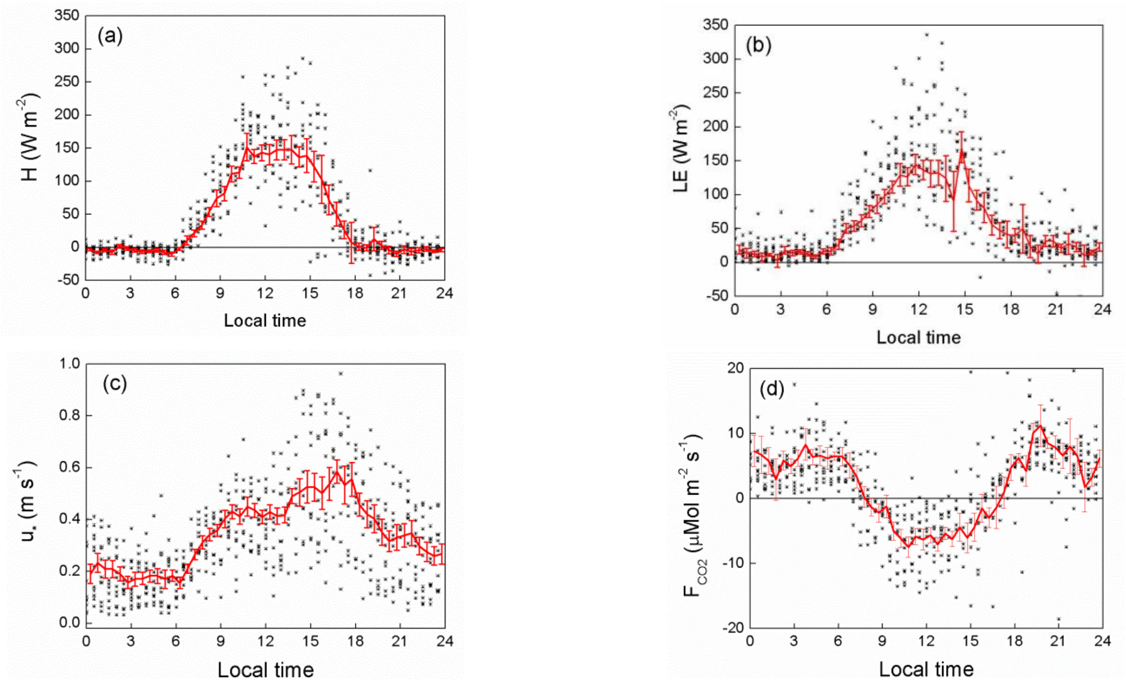


Figure 7: *Diurnal evolution of turbulent vertical fluxes of (a) Sensible heat, (b) Latent heat, (c) friction velocity and (d) CO_2 observed during the 1st Campaign carried out the MRSP in February of 2013. Observations carried out in the PM IAG.*

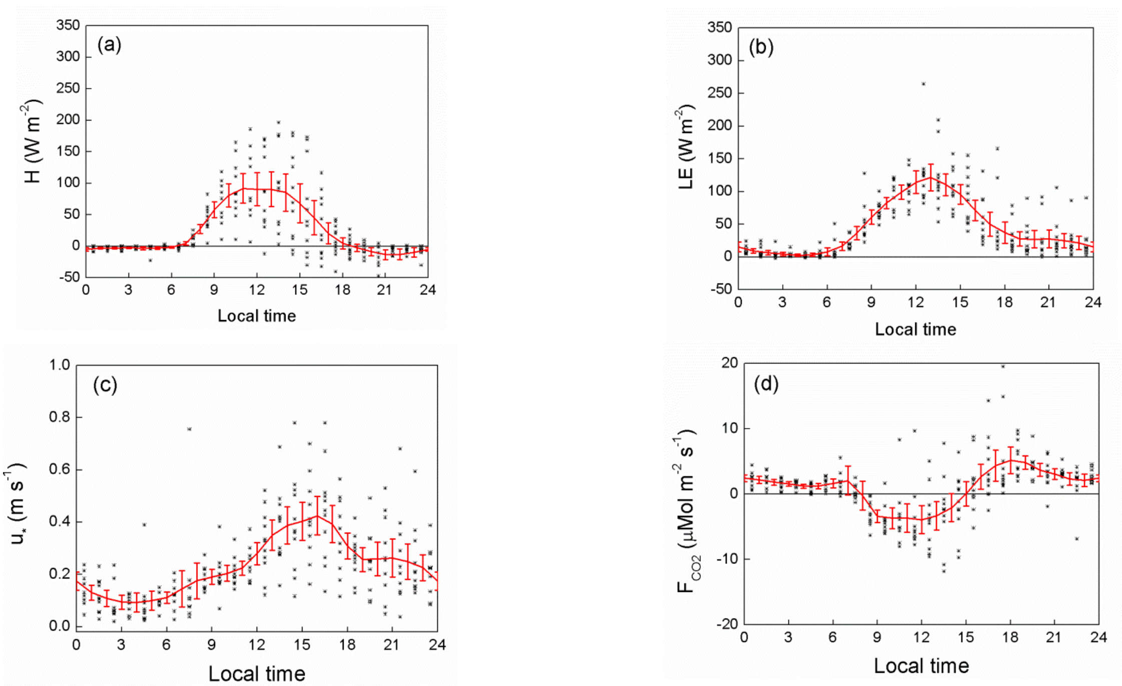


Figure 8: *Diurnal evolution of turbulent vertical fluxes of (a) Sensible and latent heat, (c) friction velocity and (d) CO_2 observed during the 2nd Campaign carried out the MRRJ in March of 2013. Observations carried out in the PM IGEO.*

Table 3. Daily values of SEB mean components during four field experiments carried out in February (1st Campaign) and August (4th Campaign) in at the PM IAG at the MRSP and in March (2nd Campaign) and July (3rd) in PM IGEO at the MRRJ.				
SEB components (MJ m^{-2} day^{-1})	Campaign			
	1st	2nd	3rd	4th
	February	March	July	August
H	6.10±0.28	2.10±1.74	1.78±0.82	3.16±0.36
LE	4.85±0.41	3.93±1.09	2.64±1.29	1.64±0.27
Bowen ratio	1.38±0.17	0.62±0.57	0.83±0.49	2.25±0.32

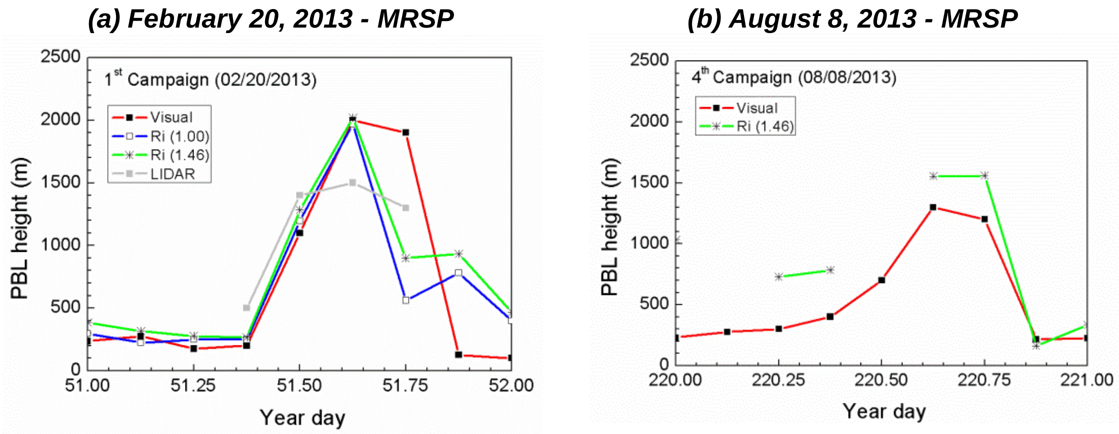


***Figure 9**. Diurnal evolution of PBL height estimated from radiosonde and LIDAR carried out during field campaigns in São Paulo in (a) February 20 (Year day 51) and (b) August 8, 2013 (Year day 220).*

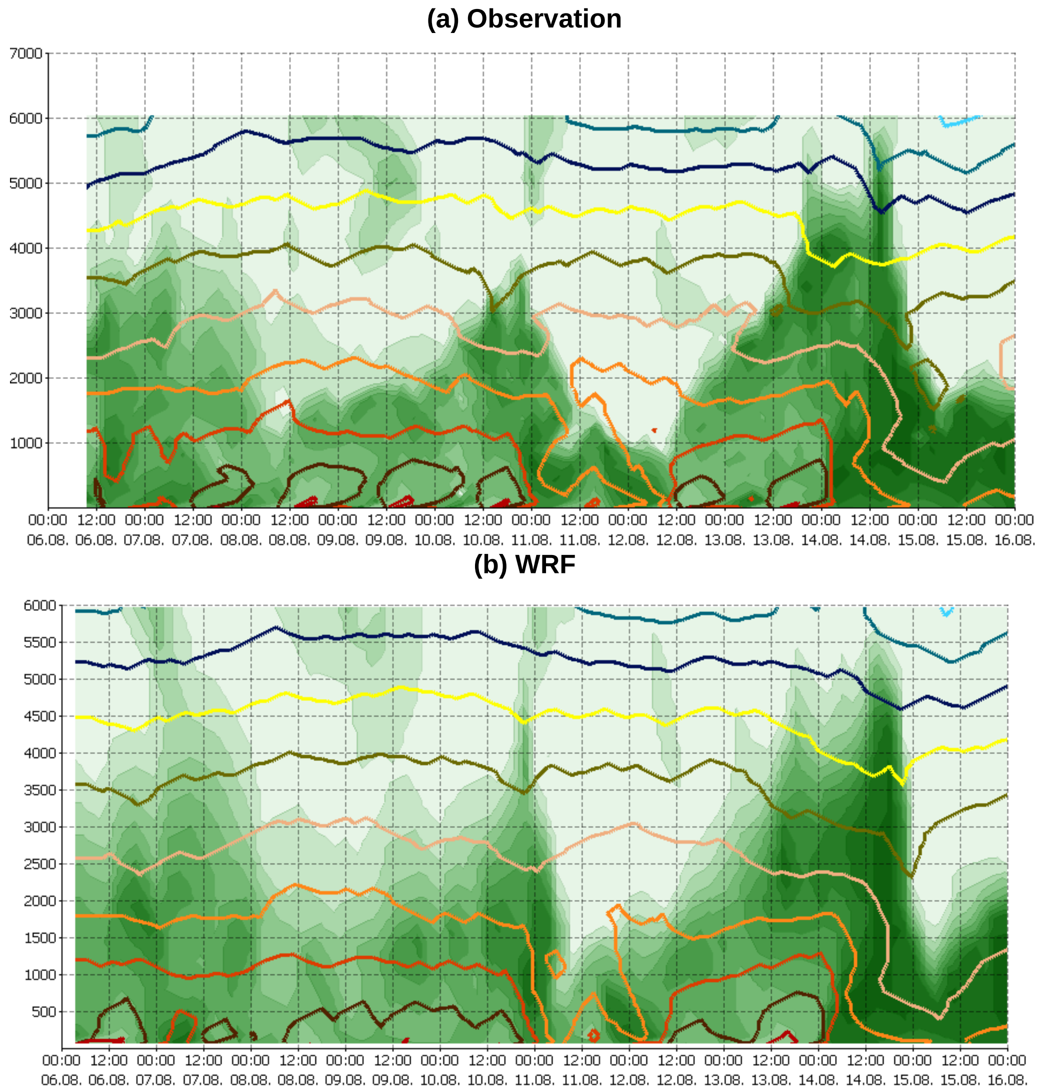


***Figure 10**. Time evolution of temperature and relative humidity (a) observed (b) simulated numerically by WRF model for the period of 4th campaign carried out in August in the MRSP.*

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References

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