Urban Climate 5 (2013) 36–51

Contents lists available at SciVerse ScienceDirect

Urban Climate

journal homepage: www.elsevier.com/locate/uclim

Diurnal variation in stored energy flux in São Paulo city, Brazil

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A R T I C L E   I N F O

Article history:
Received 9 October 2012
Revised 25 May 2013
Accepted 10 June 2013

Keywords:
Energy flux storage
Net radiation
Urban heat island
Energy balance
São Paulo city
Urban climate

A B S T R A C T

This work describes the diurnal variation in energy flux storage in the city of São Paulo, Brazil. Monthly average hourly values for the storage of energy flux were estimated using the energy balance residual and parameterisation methods. The energy balance residual method used in situ observations of net all-wave radiation and turbulent fluxes of sensible and latent heat. The anthropogenic heat flux and horizontal net heat advection were not considered. The parameterisation method, based on the objective hysteresis model, used net all-wave radiation and land use information inferred from a 1-km radius area centred at the main observational site. Using the residual balance method, the maximum diurnal evolution in monthly average hourly values of energy flux storage occurred approximately 2 h earlier than the net all-wave radiation. Using the parameterisation method to estimate energy flux storage, the daytime integrated values correspondedto approximately 51% of the net all-wave radiation and daily values to approximately 27%. The diurnal evolution in urban heat island intensity, based on monthly average values, reached a maximum intensity of 3.3 °C and a minimum of, did not show a correlation with the energy flux storage during the time period considered in this work.

1. Introduction

Over the past 200 years, the industrial revolution has fostered unprecedented growth in the urban population, resulting in the construction of large cities (Decker et al., 2000; Seto et al., 2010). This phenomenon has sped up considerably in the last 60 years, such that the number of cities with

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2212-0955/$ - see front matter
http://dx.doi.org/10.1016/j.uclim.2013.06.001

populations greater than 10 million (megacities) increased from 1 (New York City Metropolitan Area, USA) in 1950 to 19 in 2010 (Seto et al., 2010). In terms, the urban fraction varied from 29.1% in 1950 to 50.6% in 2010 (Fig. 1), and it is expected to increase to 59.7% in 2030 (UN, 2011). Considering only regions within developed countries, the urban fraction rose from 52.5% in 1950 to 75% in 2010, and it is expected to increase to 80.6% in 2030.

For Brazil, the urbanisation process has been much more intense than the global average and surpassing developed countries during the 1980s, increasing from 36.2% in 1950 to 86.5% in 2010 and is expected to reach 91.1% in 2030 (UN, 2011; IBGE, 2011). The time evolution of the population increase in São Paulo (SP) between 1950 and 2010 mirrors the intense urbanisation experienced by Brazil over the last 60 years (Fig. 1) while the population of SP increased 5.14 times, increasing from 2.2 to 11.3 million, the population of Brazil increased 3.67 times, swelling from 51.9 to 190.7 million. The largest growth was experienced by the Metropolitan Region of São Paulo City (MRSP); its population increased 7.58 times between 1950 and 2010 growing from 2.6 to 19.7 million. The urbanisation process experienced by Brazil during the last 60 years surpassed the global mean as well as developed countries (Fig. 1) and was related to the concentration of industrial areas, such as MRSP, attracting vast numbers of unemployed or underemployed workers from rural areas, where progressive mechanisation has been a consequence of agribusiness expansion (Maricato, 2003).

Urban areas in general and megacities in particular, display the most dramatic examples of the environmental problems associated with land use change. Although megacities in developed countries have placed enormous stresses on local environmental and economic resources, the quality of life of their growing populations has not been significantly affected. Alternately, in developing countries, the substantially more rapid growth of cities has led to shortages of basic social services, a lack of infrastructure and chronic air and water pollution impacts (Decker et al., 2000; Seto et al., 2010; Collier, 2006).

Because urbanisation processes have occurred on a global scale, they may have also contributed to global climate change (Grimmond, 2007; Mills, 2007). Urban areas correspond to a small fraction of the Earth's surface, i.e., 3–5% (Seto et al., 2010); they are therefore not likely to have a direct thermal impact on the temperature globally. However, there are indications that greenhouse gas (GHG) emissions from urban areas represent 30–40% of the total anthropogenic emissions; consequently, urban emissions of GHG may have a significant effect on global climate change (Dodman, 2009). In Brazil, the city of São Paulo contributes 28% of the national per capita emissions of GHG (Dodman, 2009). Despite lingering uncertainties concerning the role played by urbanisation on global climate change, there is an increasing awareness that this change, as predicted by Intergovernmental Panel on Climate Change scenarios, may affect urban climate, exacerbating the problems resulting from local changes caused by urbanisation (Collier, 2006; Grimmond, 2007; Grimmond et al., 2010).

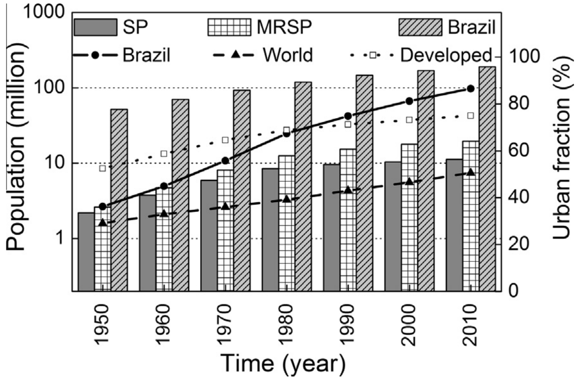

Fig. 1. Population in the megacity of São Paulo (SP), Metropolitan Region of São Paulo (MRSP) and Brazil between 1950 and 2010. Urban fraction of Brazil, world and developed country populations between 1950 and 2010 (UN, 2011; IBGE, 2008).