Urban Climate 17 (2016) 102–115

Contents lists available at ScienceDirect

Urban Climate

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

A modeling analysis of urban canopy parameterization representing the vegetation effects in the megacity of São Paulo

Marcos Vinícius Bueno de Morais [a,*], Edmilson Dias de Freitas [a], Viviana Vanesa Urbina Guerrero [a], Leila Droprinchinski Martins [b]

[a] Atmospheric Science Department, Institute of Astronomy, Geophysical and Atmospheric Science, University of São Paulo; Rua do Matão, 1226 – Cidade Universitária, 05508-090, São Paulo, SP, Brazil

[b] Department of Chemistry, Federal University of Technology – Paraná, Pioneiros Avenue, 3131, 86036-370 Londrina, PR, Brazil

ARTICLE INFO

Article history:
Received 1 September 2014
Received in revised form 9 March 2016
Accepted 28 April 2016
Available online xxxx

Keywords:
Urban heat island
Urban vegetation
Urban effects mitigation
VTEB

ABSTRACT

The representation of the influence of vegetation on meteorological variables inside the urban canopy is a modeling challenge. The interaction of vegetation canopy parameterization for urban regions in mesoscale modeling was implemented and analyzed in this work. The BRAMS model equipped with the TEB was used to simulate a calm wind and clear sky period in the Metropolitan Area of São Paulo. The impact of vegetated areas on cities was estimated by calculating the surface fluxes due to vegetation and artificial materials, weighing individual contributions by using each component fraction inside a model grid. An evaluation of the vegetation impact on atmospheric conditions was made by comparing simulated temperature and specific humidity with surface observations, atmospheric sounding values and land-surface temperature product retrieved from MODIS/TERRA. The inclusion of vegetation clearly improves the simulated air temperature, the vertical structure of the urban boundary layer and the calculation of surface fluxes. Although some improvements in the model are still necessary, it is clear that the model is very sensitive to the presence of the vegetation and continuous efforts should be made to better understand the related process and to provide better tools for urban planning and other important activities in urban areas.

* Corresponding author.
E-mail addresses: morais@usp.br, mvbdemorais@gmail.com (M.V.B. Morais)

http://dx.doi.org/10.1016/j.uclim.2016.04.004

1. Introduction

Since the industrial revolution in the mid-20th century, the world has seen a great urban migration from rural areas. As the urban population grows, the modification of the natural environment is noticeable, directly affecting the local microclimate (Kalnay and Cai, 2003). This urbanization, with its heat releases and other anthropogenic factors, results in a well-known effect, called the urban heat island (UHI; Oke, 1987). Since the end of the last century, a considerable effort in the development of parameterizations in mesoscale numerical models simulating the properties of the Urban Boundary Layer (UBL) has been made to better represent the UHI. This was due to the existing lack of observational data on the UBL and the difficulties in obtaining them with the temporal and spatial resolution needed for environmental management, weather and climate applications. As suggested by Oke (1987), the representation of urban areas in models can be made through the canyon approach, where two vertical walls representing buildings are considered to represent the frictional wind stress field and the shadow effect on the momentum and heat balance. Another important feature of this kind of representation is the influence of the building's height on the size of turbulent eddies.

In modeling studies and applications, the urban regions can be parameterized by simple layer (Masson, 2000; Kusaka et al., 2001) or multi-layered (Martilli et al., 2002; Hamdi and Masson, 2008) schemes. The main difference between them is related to the representation of the building's height. In simple layer schemes, the buildings have all the same height while in multi-layered schemes a single grid point can have several heights represented by a fraction. Both representations have been very successful in simulating mesoscale phenomena in large urban regions, such as the urban breeze in Paris (Lemonsu and Masson, 2002), the urban heat island in Basel (Hamdi and Schayes, 2008), and the so-called "chain flow" observed by Ohashi and Kida (2002), also detected in the Metropolitan Area of São Paulo (MASP; Freitas and Silva Dias, 2005; Freitas et al., 2007). The choice of the model and the parameters to be used will depend on the purpose of the study. Grimmond et al. (2011) shows a comparison between several existing models and their applications.

The application of urban canopy-atmosphere interactions models is also verified in some studies over South America. Karam et al. (2009) developed the t-TEB (*Tropical* Town Energy Budget), based on Masson (2000) model, to better represent atmospheric conditions in tropical regions. Their results showed that t-TEB simulations are consistent with the observations for the Metropolitan Area of Rio de Janeiro, suggesting that the timing and dynamics of the UHI in tropical cities could vary significantly from the familiar patterns observed in mid-latitude cities. For MASP, Marciotto et al. (2010) using a second-order closure model coupled to an urban scheme made some simulations with the goal of assessing the impact of urban canopy geometry in the vertical structure of the UBL. It was shown that a high aspect-ratio, or tall buildings, tends to reduce the surface temperature and the sensible heat flux; the magnitude of inertial oscillations of the wind above the surface boundary layer tends to grow with the aspect-ratio. For Lima, Perú, Arellano Rojas (2013), using the WRF-Chem model (Grell et al., 2005), showed that the urban area, represented as a simple layer parameterization, can have a significant role in the process of air pollution dispersion in the region, despite the great influence of the topography and sea breeze circulations. Recently, Urbina Guerrero (2016) used the BRAMS-TEB coupling to represent the Metropolitan area of Santiago, Chile, and urban caused effects on air pollution, characterizing the anthropogenic heat fluxes on the surface and the atmospheric energy budget.

Since a city is not composed only of artificial materials, parameterizations that are able to represent the vegetation inside the cities have recently been developed. Lee and Park (2007) developed the VUCM (Vegetation Urban Canopy Model), which proved to be able to represent the observed data in the cities of Marseille and Vancouver. More recently, Lemonsu et al. (2012) validated the TEB-Veg (*Town Energy Budget with Vegetation*), where the effects of vegetation on short and long wave radiation were added for simplified regions, as bare soil and grass, in the parameterization proposed by Masson (2000). TEB-Veg presented a better representation of the observational data, especially at night, when the radiation trapping effect is the dominant process.

Some studies have shown the benefits of vegetation in urban areas. Sheets and Manzer (1991) showed that the addition of vegetation in an urban street improves the quality of people's lives. Despite the cognitive results, Lee and Maheswaran (2010) showed that green spaces have a beneficial health effect.

On the precipitation, although the expected increasing effect due to the higher moisture (Burian et al., 2002), Jauregui (1990) showed that the convective precipitation can be lower in parks. This was attributed to the reductions of low-level wind speed, caused by taller trees in the park, increasing the turbulence intensity. Another effect of vegetation is seen on air quality. Taha (1996), using a mesoscale model with a photochemical module, showed that the vegetation decreases the ozone concentrations, using hydrocarbon-