A PRELIMINARY EVALUATION OF VEHICLE EMISSIONS FROM PM_{10} IN THE METROPOLITAN REGION OF SALVADOR USING THE WRF-SMOKE-CMAQ MODELS SYSTEM

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Abstract: The metropolitan region of Salvador (RMS), Bahia, Brazil, lacks studies on the transport of air pollutants using air quality models. In this sense, this work seeks to carry out a preliminary study of the transport of pollutants in the RMS using an inventory of vehicle emissions for the year 2015, based on the methodology available in the literature (National Inventory of Atmospheric Emissions by Road Motor Vehicles). For the analysis of particulate matter emissions (MP_{10}), the integrated modeling system WRF-SMOKE-CMAQ was used. The simulations showed maximum values of 15 μg/m^3 and 12 μg/m^3 for 7 am and 1 pm, on June 30, 2015, respectively. Although simulations are presented for just one day, the results show the importance of these studies as a tool to help manage air quality.

Keywords: Metropolitan Region of Salvador, WRF-SMOKE-CMAQ, PM_{10}.

UMA AVALIAÇÃO PRELIMINAR DAS EMISSÕES VEICULARES DE PM_{10} NA REGIÃO METROPOLITANA DE SALVADOR UTILIZANDO O SISTEMA DE MODELOS WRF-SMOKE-CMAQ

Resumo: A região metropolitana de Salvador (RMS), Bahia, Brasil, carece de estudos sobre o transporte de poluentes atmosféricos usando modelos de qualidade do ar. Neste sentido, este trabalho busca realizar um estudo preliminar do transporte de poluentes na RMS utilizando um inventário de emissões veiculares para o ano de 2015, com base na metodologia disponível na literatura (Inventário Nacional de Emissões Atmosféricas por Veículos Automotores Rodoviários). Para análise das emissões de material particulado (MP_{10}) foi utilizado o sistema integrado de modelagem WRF-SMOKE-CMAQ. As simulações mostraram valores máximos de 15 μg/m^3 e 12 μg/m^3 para as 7 h e 13 h, no dia 30 de junho de 2015, respectivamente. Apesar de serem apresentadas simulações somente para um dia, os resultados mostram a importância destes estudos como ferramenta no auxílio à gestão da qualidade do ar.

Palavras-chave: Região Metropolitana de Salvador, WRF-SMOKE-CMAQ, PM_{10}.

1. INTRODUCTION

Although strategies and actions aimed at improving air quality are used in Brazil, there is still a shortage of information regarding local emissions as well as their application in air quality models. The characterization of atmospheric emissions is essential to understand these interactions in urban regions. In this sense, an inventory of pollutant emissions has been a fundamental tool for this understanding [1,2].

Large urban centers have been the focus of studies aimed at assessing air quality, as these are regions most susceptible to critical scenarios. Air pollution is still a major environmental problem, as it directly affects the health of the population, the environment and the economy. In recent years, in order to understand the complex interactions of air pollutants, with technological advances, the scientific community has been developing models of analysis and forecasting air quality with high performance [3,4,5].

In general, emissions inventories provide total annual emissions. However, air quality models usually require hourly emissions data, for each grid cell and for each modeled species. Thus, this processing requires a series of transformations such os temporais allocation, chemical speciation and spatial allocation, to obtain the input data required by the air quality model [1].

Therefore, this study aims to carry out a preliminary assessment of the estimated data according to the current legislation, more specifically the particulate material, using the state of the art in air quality represented by the WRF-SMOKE-CMAQ model system, including a recent inventory of mobile fountains carried out in the metropolitan region of Salvador (RMS) [1,2].

2. METHODOLOGY

2.1 Study area

The RMS is composed of 13 municipalities and is located between latitudes 12° 20'S and 13° 10'S and longitudes 37° 50'W and 38° 50'W, as shown in Figure 1. Its economy consists of industry, commerce, tourism and services. The region has a humid tropical climate, which is characteristic of the southeast and northeast of Brazil.

The highest volumes of precipitation occur in the period of April/July and the lowest between September/December and the average annual temperature is 26ºC [6]. The region does not have well-defined seasons, being characterized by a dry and a rainy season, where the analyzed period is inserted in the interval that comprises the rainy season, characterized by milder temperatures and warmer weather.

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Figure 1 - Study area.

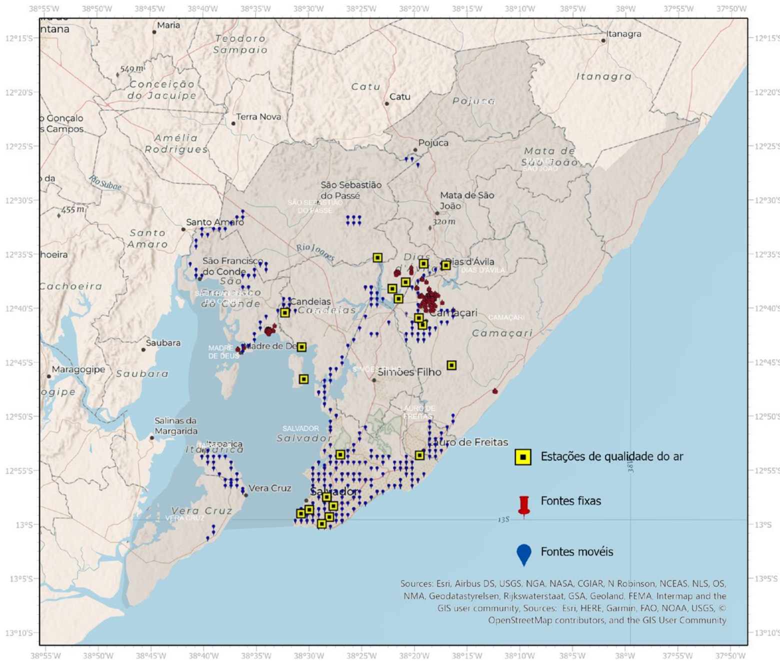

Figure 1 represents the RMS, with a total area of approximately 4,375,123 km² and 3,929,209 inhabitants [7]. In highlight, there are air quality stations (yellow), fixed sources (red), and mobile sources (blue), for this work only mobile sources (road vehicles) are considered.

As it is an urban-industrial region where the capital of the State is located, the number of motor vehicles in the RMS represents 30% of the total of the State of Bahia. In addition, it covers the Landulfo Alves Refinery (RLAM), the Aratu Industrial Center (CIA) and the Camaçari petrochemical complex. The export of products occurs predominantly on the highways and the region needs studies with the use of chemical transport models, which is why it is the region of interest.

2.2 Modeling with WRF-SMOKE-CMAQ.

The simulations were performed using the integrated modeling system WRF-SMOKE-CMAQ.

Figure 2 shows the nesting of three grids using the WRF meteorological model, with a resolution of 9 km (39 × 39 cells), 3 km (60 × 60 cells) and 1 km of grid (132 × 132 cells), as shown in Figure 2, with 23 vertical levels [8].

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Figura 2 - Simulated domains.

The meteorological fields were generated by the WRF model, version 3.9.1, and their outputs were used by the MCIP model, in order to create input data required by SMOKE and CMAQ. The simulated period comprises part of the rainy period (June 23 to July 23), with June 30, 2015 being the chosen day [3].

The initial and boundary conditions came from the global tropospheric analysis data set of the GDAS/FNL operational model, available at a resolution of 0.25 degrees every 6 hours [3]. Topography and vegetation coverage data were provided by the USGS (US Geological Survey) in resolutions of 5 min, 2 min and 30 s. The physical configurations adopted are shown in Table 1.

Table 1. Configuration of the WRF model for the simulation.

Physical parameterization	**Scheme**	**References**
Microphysics	Kessler	Kessler (1969)
Cumulus	Kain–Fritsch	Kain (2004)
Short-wave radiation	Dudhia	Dudhia (1989)
Long wave radiation	Rapid Radiative Transfer Model (RRTM)	Mlawer et al. (1997)
Surface Layer	MM5 similarity	(Fairall et al. 2003)
Planetary Boundary Layer	Mellor-Yamada, Nakanishi and Niino 2.5	Nakanishi and Niino (2006)
Surface model	Noah land surface scheme	(Niu et al. 2011)

The chemical transport model CMAQ, version 5.2.1, was used to assess air quality [3]. The boundary conditions (BC) used by the D03 domain were generated by the simulations performed with the D01 domain. The initial conditions (CI) for both domains used static concentrations and was estimated by the CB05 gas mechanism, of the sixth generation for aerosol [8].

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3. RESULTS AND DISCUSSIONS

To understand the chemical transport of pollutants, as well as their hourly variation influenced by atmospheric turbulence, factors such as the average hourly variation of the planetary boundary layer (CLP) and the average hourly variation of temperature in the region were considered [9], as shown in figure 3.

Figure 3 - Average hourly variation: (a) PLC height; (b) temperature.

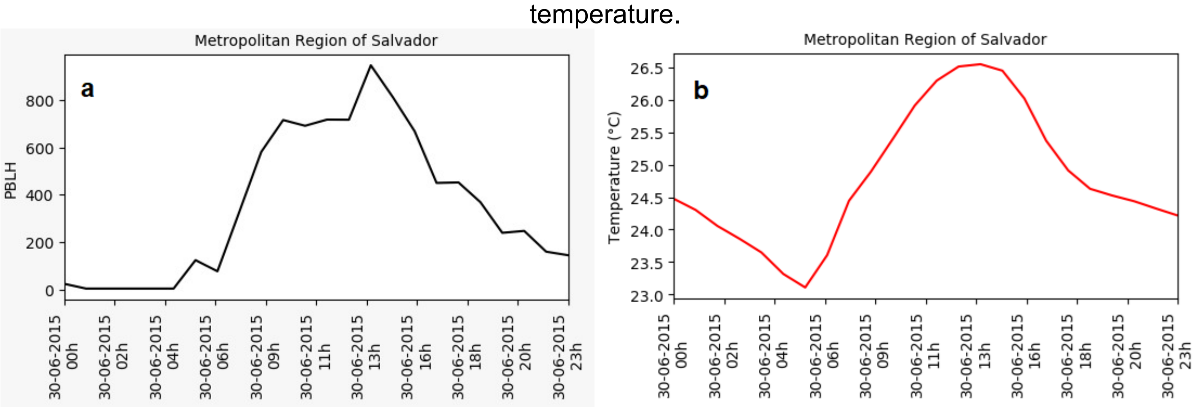
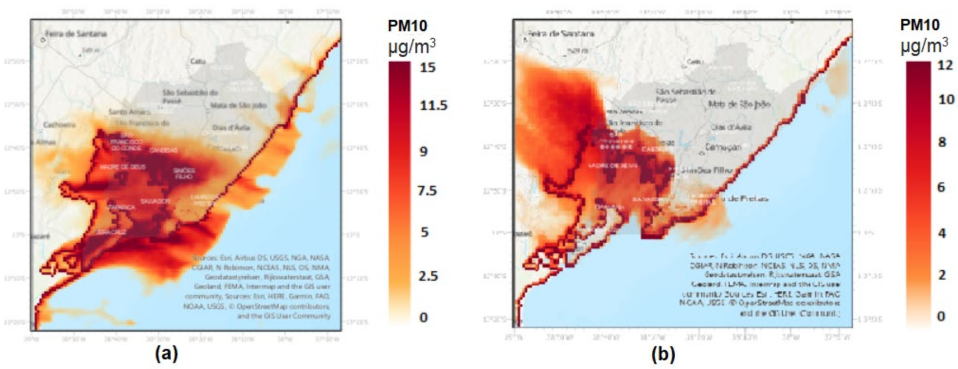


Figure 3 (a) shows the hourly average height of the CLP for June 30, 2015, and Figure 3 (b) represents the hourly average temperature for that day. In Figure 3 (a) it is observed that around 6 am in the morning an increase in CLP height starts, reaching a maximum value around 2 pm, and decreasing during the day. Similar behavior was found in Figure 3 (b) for the hourly average temperature. The results are in line with the expected and this behavior is fundamental for the analysis of the dispersion of pollutants in the atmosphere.

In RMS, the highest traffic volumes occur in the city of Salvador, Lauro de Freitas and Camaçari [7]. Figures 5 (a) and 5(b) shows PM10 concentrations for June 30, 2015, at 7 am and 1 pm, respectively.

Figure 5 - PM10 concentration in the RMS: (a) 7 h; (b) 13h.



It is observed in Figure 5 (a), at 7 am, a maximum value of 15 µg / m3 and, in Figure 5 (b), at 13 h, a maximum value of 12 µg / m3. These times are representative with higher concentrations of PM10 because they are periods when the flow of vehicles is more intense. In addition, there is a greater transport of pollutants to the interior due to the more intense wind in the afternoon, and also due to the increase in PLC, causing a greater dilution of pollutants in the atmosphere.

4. CONCLUSÃO

The main objective of this study was the preliminary analysis of emissions from road vehicles in the RMS using the WRF-SMOKE-CMAQ modeling system, which is the state of the art for the assessment of air quality. This type of modeling represents an initial advance regarding the complexity of the interactions of air pollutants in the region.

The maximum values found show good results in the local air quality, for the simulated period, as they are with low levels, although data measured at monitoring stations are not presented at this moment for comparison with the simulations. In addition, only mobile sources were taken into account in the simulations, and the RMS has many fixed sources.

The study demonstrates the importance of preparing local emission inventories as a tool for managing air quality, providing important information for structuring the Vehicle Pollution Control Plan (PCPV), assessing the performance of technologies and environmental legislation.

For future work it is proposed to perform the regional photochemical modeling of air quality with the WRF-SMOKE-CMAQ modeling system taking into account a longer simulated period, including fixed sources and using monitoring data to analyze the air quality in the region.

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5. REFERENCES

[1]LORIATO, Ayras G.; SALVADOR, Nadir; LORIATO, Ayran A. B.; SOKOLOV, Anton; NASCIMENTO, Antonio P.; YNOUE, Rita Y.; MOREIRA, Davidson M.; REIS Jr., Neyval C.; ALBUQUERQUE, Taciana T. A. “Inventário de Emissões com Alta Resolução para a Região da Grande Vitória Utilizando o Sistema de Modelagem Integrada WRF-SMOKE-CMAQ.” **Revista Brasileira de Meteorologia**, v.33, n. 3, pp. 521-536, 2018. DOI:10.1590/0102-7786333011.

[2]DA SILVA, KS. Especiação das emissões atmosféricas por fontes móveis na Região Metropolita na de Salvador. Dissertação de Mestrado em Modelagem Computacional e Tecnologia Industrial, Programa de Pós Graduação, **Centro Universitário SENAI CIMATEC**: Salvador, 2020.

[3]JIMÉNEZ, P.A., DUDHIA, J., GONZÁLEZ-ROUCO, J.F., NAVARRO, J., MONTÁVEZ, J.P. & GARCÍA-BUSTAMENTE, E., “A revised scheme for the WRF

Surface Layer Formulation”. **Monthly Weather Review**, 140, pp. 898–918, 2012. DOI: 10.1175/MWR-D-11-00056.1.

[4]VELLOSO, Maria FA et al. Avaliação dos modelos de qualidade do ar AERMOD e ISC para a região de Nova Iguaçu, RJ. **Ciência e Natura**, p. 371-374, 2007.

[5]SILVA JÚNIOR, Rosiberto Salustiano da. Sensibilidade na estimativa da concentração de poluentes fotoquímicos com a aplicação de diferentes parametrizações de camada limite planetária utilizando o modelo de qualidade do ar WRF/Chem. Tese de Doutorado. **Universidade de São Paulo**. 2009.

[6]INSTITUTO NACIONAL DE METEOROLOGIA (INMET). Estações e dados. **Banco de dados meteorológicos**. Disponível em: <https://portal.inmet.gov.br/>. Acesso: em 25 de junho 2020.

[7]INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA (IBGE). Cidades e Estados. **Censo**. Disponível em:< http://www.censo2010.ibge.gov.br/>. Acesso em agosto 2019, v. 23, 2010.

[8]KITAGAWA, Y.K.L. et al., “Evaluation of the chemical transport of air pollutants in the metropolitan region of salvador, brazil”. **WIT Transactions on Ecology and the Environment**, v. 230, p. 519-530, 2018.

[9]DEGRAZIA, Franco Caldas. Evolução de camada limite planetária para dispersão de poluentes pelo método da GILTT. 2005.