Evaluation of planetary boundary layer parameterizations with the WRF model in the Metropolitan Region of Salvador.

Anderson da Silva Palmeira[1,a], Patrick Silva Ferráz [b] e Davidson Martins Moreira [a]

[a] SENAI CIMATEC University Center, Salvador, Bahia
[b] Federal university of Bahia, Salvador, Bahia

Abstract: Evaluation of the parameterization of the PBL Planetary Boundary Layer in the Metropolitan Region of Salvador using the Weather Research and Forecasting (WRF) model. The performance of numerical simulations was evaluated using radiosonde data. The physical parameterizations used in the model showed good agreement for temporal comparisons of vertical and horizontal wind speeds and wind directions predicted by the WRF model. The main objective of this initial study is to evaluate the performance of the physical parameterization of the model for the behavior in the PBL. The proposed initial study shows good agreement between the simulated and measured data, but the evaluation of the PBL for the period does not suggest a characterization of the Internal Boundary Layer.

Keywords: WRF, Radiosonde, PBL.

Avaliação de parametrizações da Camada Limite Planetária com o modelo WRF na Região Metropolitana de Salvador.

Resumo: Avaliação de parametrizações da Camada Limite Planetária CLP na Região Metropolitana de Salvador utilizando o modelo Weather Research and Forecasting (WRF). Avaliou-se o desempenho das simulações numéricas utilizando dados de radiossondagem. As parametrizações físicas utilizadas no modelo mostraram boa concordância para comparações temporais das velocidades vertical e horizontal do vento e direções do vento previstas pelo modelo WRF. O objetivo principal deste estudo inicial é avaliar o desempenho da parametrização física do modelo para o comportamento na CLP. O estudo inicial proposto mostra boa concordância entre os dados simulados e medidos, porém a avaliação do CLP para o período não sugere uma caracterização da Camada Limite Interna.

Palavras-chave: WRF, Radiossonda, CLP.

1. INTRODUCTION

Along coastal regions, the Planetary Boundary Layer (PBL) has a different internal behavior, due to the thermal differential between sea and land, daily variations that can significantly alter local circulation. Thus, the dynamics of the Inner Thermal Boundary Layer (TBL), which is formed by the sea breeze, has been studied by several researchers, including [2-9] [11] [14-20]. However, short-term events such as TBL are difficult to detect and their PBL investigation is very important in atmospheric studies, their influence on the local PBL can affect the dispersion of pollutants, mathematical models are evaluated to make predictions about these circulations, mainly studies on the influence of pollutants according to [19,20].

Pollutants are transported over long distances by a large-scale wind field, and their dispersion is the result of a set of multi-dimensional vortices generated by large-scale imbalances by several factors, such as thermal differentials, terrain, types, and use of soils etc. [12]. Such factors generate turbulence and movements on a smaller scale, which play an important role in the dispersion of atmospheric pollutants. However, other factors in TBL may occasionally contribute to increased concentrations of pollutants, causing discomfort and damage to health for individuals living close to emission sources [1].

The main objective of this initial study is to evaluate the performance of a physical parameterization of the Weather Research and Forecasting (WRF) mesoscale model for the behavior of the PBL proposed by [19,20], which may influence studies that examine the effects of pollutants in the vicinity of the Metropolitan Region of Salvador (RMS) in the state of Bahia, Brazil.

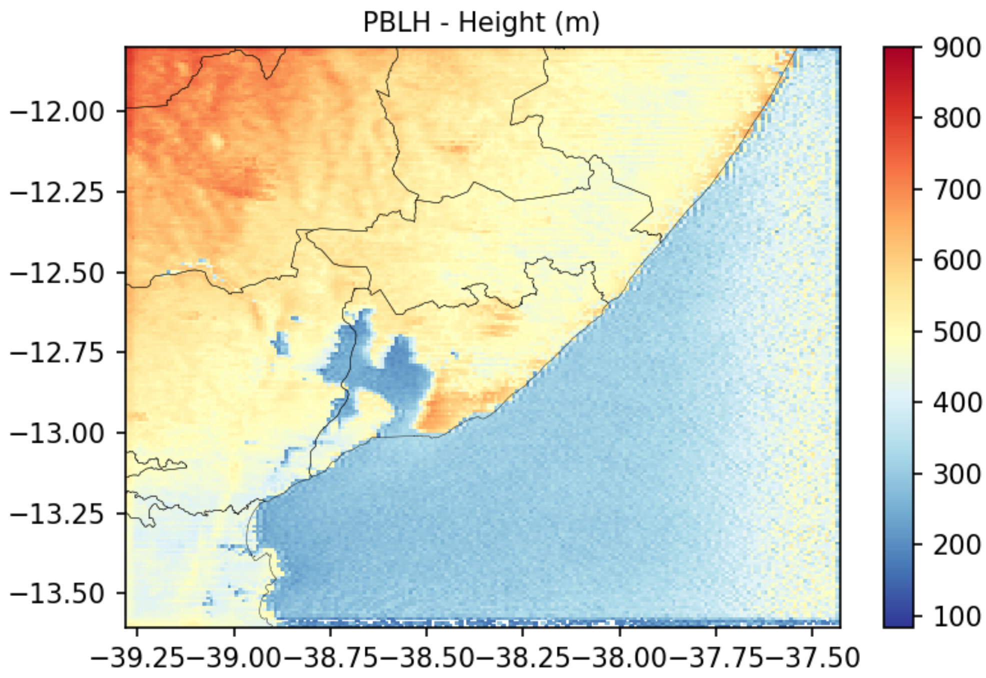
To validate the simulations, observational data were collected using Surface Meteorological Stations (SMS) and Radiosonde. It is important to emphasize that it is difficult to evaluate the profile of the PBL for studies of pollutant concentration, and normally the phenomena are of short duration, in addition to the difficulty of availability of experimental data due to the costs involved and the dependence on meteorological conditions [19]. Thus, this study presents the results of comparative numerical modeling using experimental radiosonde data from a one-day trial performed in 2015 on the sea breeze in the RMS. This initial study evaluates parameterizations in a coastal region, accounting for a comparison with observed data obtained from radiosonde measuring equipment.

This article is organized as follows: section 2 presents the sequence in which the research was carried out and details the basic characteristics of the study domain, such as dimension, horizontal and vertical mesh spacing, geographic features and singularities, wind regimes, reference obtained, and the physical parameterizations used in the WRF model simulations. Section 3 presents the results generated by the WRF model, and the accuracy of each set of parameterizations in the description of the occurrence and dynamics of sea breezes is evaluated, comparing the data predicted by the model with those obtained by the instruments used during the experimental period. Finally, Section 4 reports the results closest to those obtained between modeled and observed results used during the experimental period.

2. METHODOLOGY

The following are briefly presented: the main aspects related to the field of study, the predominance of winds in the region, the use of experimental data collection equipment, the mesh used in the WRF simulations, and the respective parameterizations tested in this study.

Figure 1 – Represents the D03 domain at the center of the Metropolitan Region of Salvador domain and the average height of the PBL of this region.



The region also has complex topography with a flat portion close to the coast that extends from north to south of the RMS, permeated by several peaks with altitudes of up to 615 meters. Therefore, this region has several singularities that influence local circulations and, consequently, the transport and dispersion of pollutants, so this initial study will evaluate the PBL behavior.

2.1. WRF model set-up

The simulations were conducted using the WRF model v.3.9.1.1 with three nested domains (see Fig. 1) centered on coordinates 38.5 S and 12.75 W, where the SMS were positioned. The largest domains of three squares were 1161, 603 and 204 km with grids of 9, 3 and 1 km respectively, with approximately 13,400 m, which were concentrated closer to the ground with 43 levels of up to 400 meters spaced.

The simulations were set to run in October 2015, with a spin-up and a day. The physical parameterization schemes adopted were, Rapid Radiative Transfer Model (RRTMG) for short and long waves radiation, Thompson scheme as a microphysics option, Noah-MP as Earth surface model, Grell-Freitas as cumulus scheme, except for the of planetary boundary layer, Eta similarity as the surface layer, YSU for PBL height. Thus, the vertical resolution adopted 45 layers, and the top model at 50 hPa and horizontal grid 204 km^2.

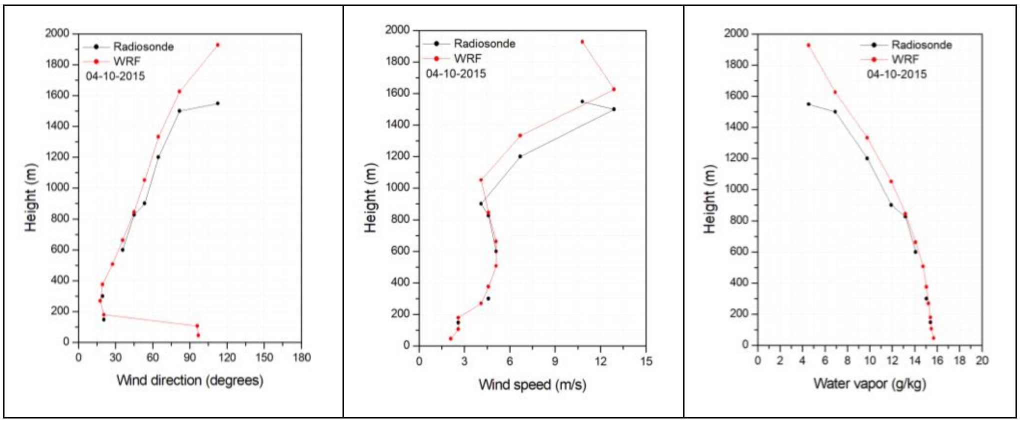
To start the WRF model, the geographic data provided by the United States Geological Survey (USGS) was used with a horizontal grid of approximately 1 km, and the NCEP FNL (Final) operational analysis and forecast data is at 0.25 degrees by networks. 0.25 degrees operationally prepared every six hours. This product is from the Global Data Assimilation System (GDAS) [10,13].

3. RESULTS AND DISCUSSION

The predictions generated by the WRF model were compared with data obtained by SMS and radiosonde. October 4-7, 2015, was selected for comparison, the day we evaluated the influence of wind direction, speed and water vapor in the PBL, with data collected by radiosonde. Compared to the data obtained by radiosonde at 9:00 local time, the data inferred from the WRF model showed satisfactory accuracy for wind direction, wind speed and water vapor (above 200 m).

A brief discussion of the height of the atmospheric boundary layer. The formula for diagnosing PBL height (h) is specific for each parameter. YSU determine the top of the PBL where the mass Richardson number exceeds a critical value, and the YSU project calculates the mass Richardson number based on the ground surface. The YSU design performed more satisfactorily in determining the PBL height for the period in the RMS. Furthermore, the results suggest that Noah's parameterization could better capture the information on the energy balance in the ground. The following figure 3 shows the average height of the PBL for the region during the month of October 2015.

Figure 2 – Represents the behavior of wind direction, speed and water vapor in the PBL up to 2000 m in height in the Metropolitan Region of Salvador from October 4th to 7th, 2015.



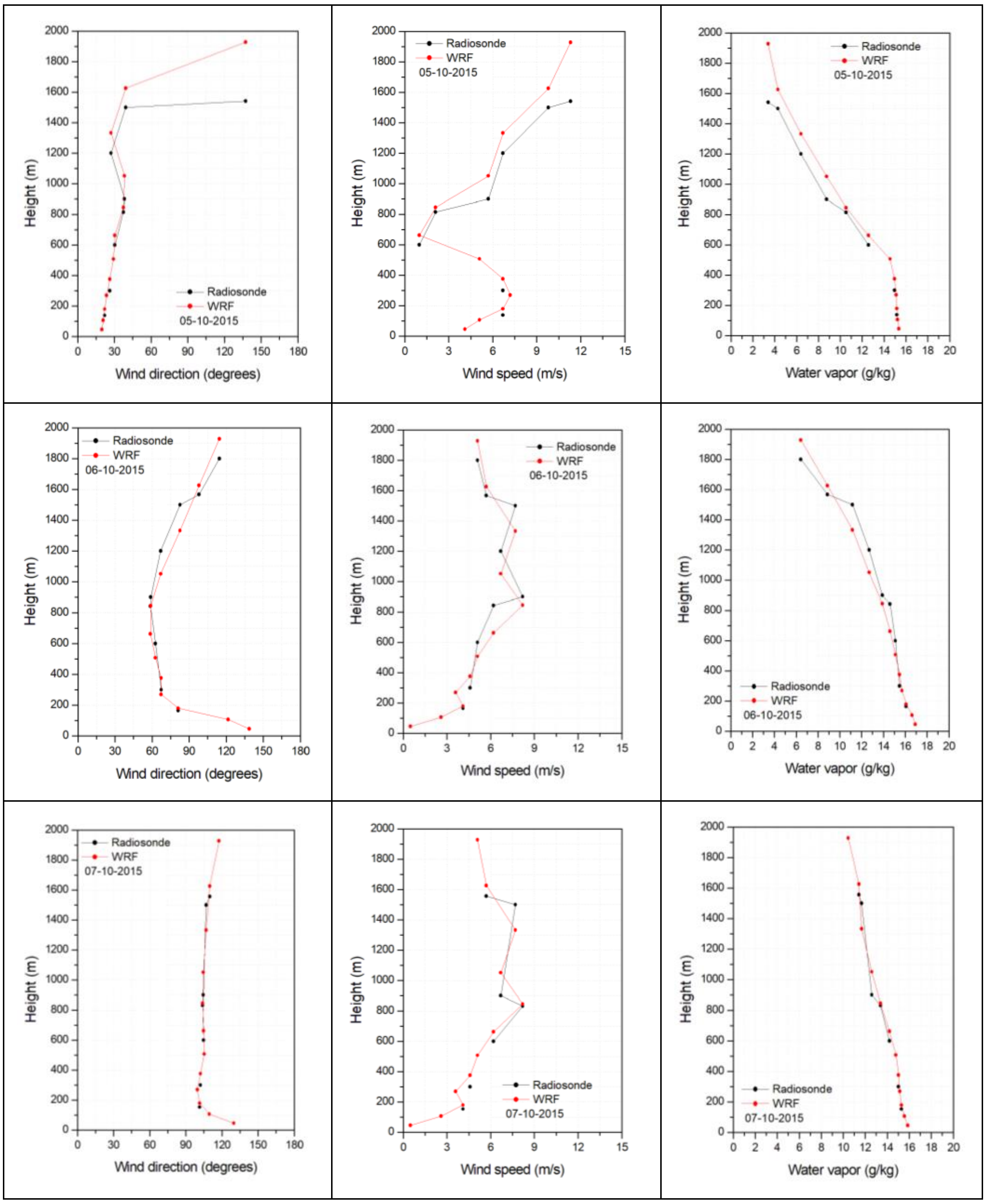


Figure 2 represents the behavior of wind direction, speed, and water vapor in the PBL up to 2000 m in height in the Metropolitan Region of Salvador from October 4th to October 7th, 2015. The simulated data observed in Figure 2 show good agreement, however the PBL assessment for the period does not suggest a TBL characterization proposed by [14-16] and [18], this assessment is important in atmospheric models because this height is used to assess the physical behavior in the study region. The PBL height is detected as the height of the neutral fluctuation level where the bulk Richardson number for entrainment exceeds a critical value [8].

This initial study shows that new verifications of the designs are necessary through additional experimental observations, which are planned for the near future in the RMS, including sampling with more days for a better characterization of the event. However, it is worth mentioning that it is also difficult to determine short-period phenomena more accurately when obtaining input data in more accurate dispersion models.

4. CONCLUSION

The present study evaluated the ability of some sets of physical parameterizations used in a WRF atmospheric model to describe the PBL in a coastal region with complex topography. The results showed that although inferences were generated for a single point in the domain and for only one day, the data inferred by the WRF model reasonably represented the structure of the atmosphere in the study region.

Although the YSU parameterization with Noah showed satisfactory results for the surface wind direction behavior. In the WRF model simulations, input data provided by the file generated by the USGS were used, describing the type of soil and its occupation and geographic singularities with a horizontal grid of approximately 1 km.

Future studies may lead to improvements in simulations with more detailed and up-to-date information from the ground in the RMS, including higher spatial resolution in the model and comparison of parameterizations for Inner Boundary Layer (TBL) studies.

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