Journal of Geoscience and Environment Protection, 2015, 3, 77-82
Published Online August 2015 in SciRes. http://www.scirp.org/journal/gep
http://dx.doi.org/10.4236/gep.2015.36013

Assessing the Impact of Using Different Land Cover Classification in Regional Modeling Studies for the Manaus Area, Brazil

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Received 11 June 2015; accepted 21 August 2015; published 25 August 2015

Abstract

Land cover classification is one of the main components of the modern weather research and forecasting models, which can influence the meteorological variable, and in turn the concentration of air pollutants. In this study the impact of using two traditional land use classifications, the United States Geological Survey (USGS) and the Moderate-resolution Imaging Spectroradiometer (MODIS), were evaluated. The Weather Research and Forecasting model (WRF, version 3.2.1) was run for the period 18 - 22 August, 2014 (dry season) at a grid spacing of 3 km centered on the city of Manaus. The comparison between simulated and ground-based observed data revealed significant differences in the meteorological fields, for instance, the temperature. Compared to USGS, MODIS classification showed better skill in representing observed temperature for urban areas of Manaus, while the two files showed similar results for nearby areas. The analysis of the files suggests that the better quality of the simulations favorable to the MODIS file is straightly related to its better representation of urban class of land use, which is observed to be not adequately represented by USGS.

Keywords

Land Use and Land Cover Classification, Regional Modeling Studies, Urban Air Quality

1. Introduction

Land cover classification is an important component of the weather research and forecasting models, especially if the simulations are performed by using coupled chemistry. Spatial distribution of different database of land cover will influence the meteorological variables, which in turn are associated with the transport and dispersion of air pollutants. This influence was noted by [1], wherein observed that the temperature in urban areas was

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How to cite this paper: Rafee, S.A.A, Kawashima, A.B., de Morais, M.V.B., Urbina, V., Martins, L.D. and Martins, J.A. (2015) Assessing the Impact of Using Different Land Cover Classification in Regional Modeling Studies for the Manaus Area, Brazil. *Journal of Geoscience and Environment Protection*, **3**, 77-82. http://dx.doi.org/10.4236/gep.2015.36013

higher than in rural areas. The increase in temperature accelerates the rate of diffusion, which leads to the formation of upward vertical movement causing increased thermal turbulence, generating entrainment of the pollutants from lower levels to higher levels. Another important aspect is the representation of forest class, where the presence of these in a region can change temperature and relative humidity. In addition, accurate representation of forest can influence the concentration of volatile organic compounds in the atmosphere and consequently the secondary chemical compounds [2] [3].

In this study, the impact of using suitable classes of land use and land cover to represent the temperature by regional atmospheric modeling was addressed for Manaus region, Brazil.

2. Materials and Methods

2.1. Study Area

The domain of study includes the urban area of Manaus and its surroundings, with a total area of 232,560 km^2 (**Figure 1**). The city of Manaus is located in the Northern Region of Brazil, in central Amazon, at coordinates 03˚06'07"S and 60˚01'30"W. Manaus has an urbanized area of approximately 230 km^2, equivalent to about 0.1% of the selected domain of study. Manaus has an estimated population of about 2 million inhabitants, representing 52% of the total population of the state of Amazonas [4].

2.2. WRF Model

The Weather Research and Forecasting model (WRF, version 3.2.1) is a non-hydrostatic mesoscale prediction and atmospheric simulation system [5]. The WRF code is available at http://www.mmm.ucar.edu/wrf/users. The WRF model was run with a grid spacing of 3 km with 190 × 136 grid points in horizontal domain, centered on the city of Manaus, at 3.07˚S and 59.99˚W. The simulation comprises the period 18 - 22 August, 2014, representing the dry season of the region. The physics configurations that were considered in the simulations are presented in **Table 1**.

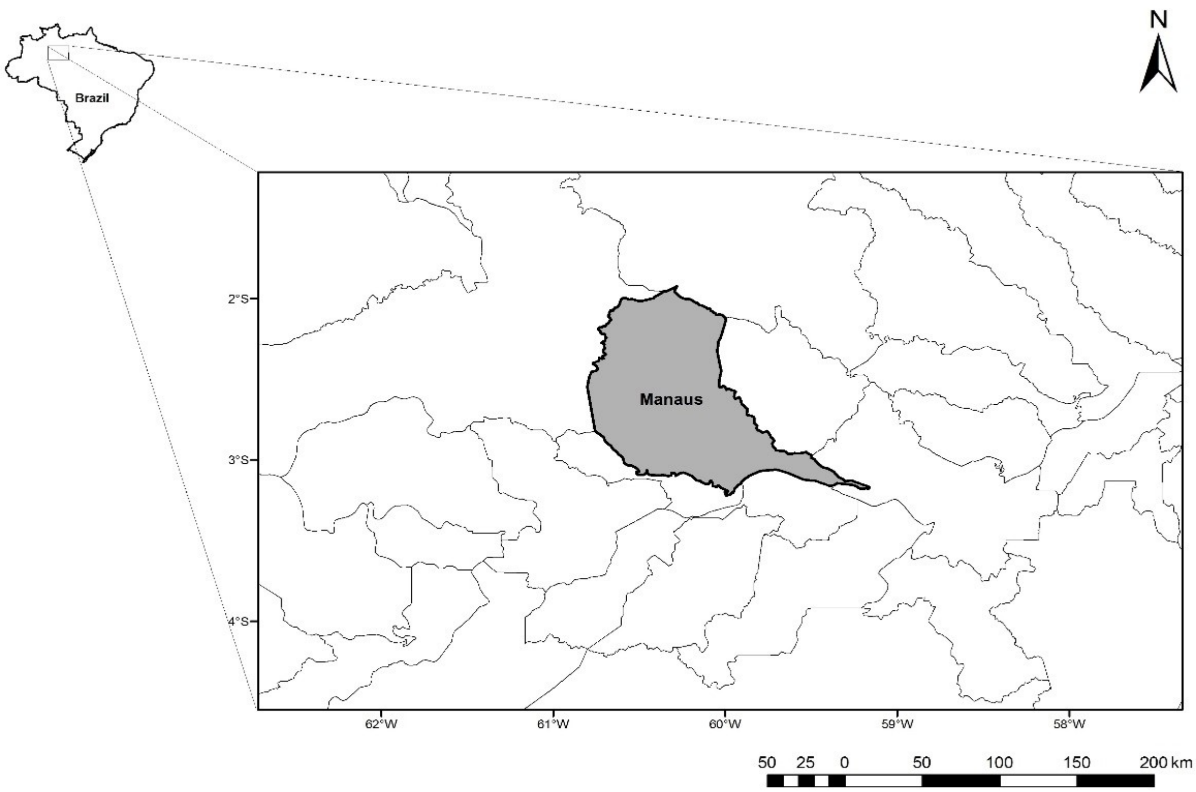

Figure 1. Geographic location of the study area.

Table 1. Physics configurations options in the WRF simulations.

Process	Scheme
Cloud microphysics	Milbrandt-Yau
Superficial layer	MM5
Land-surface	Noah
Boundary layer	Yonsei University
Short-wave radiation	Dudhia
Long-wave radiation	Rapid Radiative Transfer Model
Cumulus cloud	Grell three-dimensional

2.3. Data Sources

To evaluate the impact of land cover, two traditional classifications, the United States Geological Survey (USGS) and the Moderate-resolution Imaging Spectroradiometer (MODIS), were used. USGS data are derived from the Advanced Very High Resolution Radiometer (AVHRR) sensor, and measurements based on Normalized Difference Vegetation Index (NDVI) with a resolution of 1.0 km, obtained between from April 1992 to March 1993 [6]. The MODIS-2005, with a spatial resolution of 500 meters, comprises data acquired in 36 spectral bands distributed between the visible and thermal infrared (0.4 - 14.3 μm) [7].

Simulated temperature fields were compared with observations measured in four meteorological stations located in different sites (**Figure 2**): T1, which was located within the city of Manaus, at National Institute for Amazonian Research (INPA); T3, which was located north of Manacapuru, about 100 km from Manaus, a site of the project Green Ocean Amazon (GOAmazon, 2014); EMBRAPA_AM010, which was located at the Brazilian Agricultural Research Corporation (Embrapa) at AM-010 highway; and EMBRAPA_IRANDUBA, which was located in the municipality of Iranduba, a site associated to the Project REMCLAM Network of Climate Change Amazon.

3. Results and Discussion

Figure 3 shows a comparison between the two land cover databases used in this work. Significant differences can be observed on spatial distribution of land cover classes of the two files. The USGS classification does not recognize the urban class for Manaus city, whereas it is better represented by MODIS. Urban and built up land cover fraction is zero from USGS and 0.1% from MODIS. This later value matches the official values for urbanized area of Manaus. In terms of water bodies, there are significant differences between the two files, highlighting the fact that Balbina Reservoir, with about 2360 km^2, is not recognized as a water body by USGS. In addition, there are differences on Evergreen Broadleaf Forest.

The simulated temperature profile was observed to be in good agreement with observed ground-based data, as shown in **Figure 4**, except for T1 station, which was located in urban area of Manaus. It can be noted that the simulation with USGS file underestimated the values of temperature in urban site. In this case, the better skill showed by MODIS can be attributed to its more adequate representation of urban land cover class. The three sites where a good level of agreement is observed for both, USGS and MODIS, are those located in forested areas.

Comparing the temperature fields for the urban area of Manaus, at 13 LT, it is notable that the presence of urban area generates an increased temperature at the center of city, which is caused by the disturbed natural environment [8]. The maximum simulated temperature at 13 LT, by using MODIS, is 1˚C higher than obtained USGS is used. The parameters Pearson’s Correlation (r), Mean Bias (MB), Root-mean-square error (RMSE) and Skill of Pielke (S_{pielke}) were used to analyze the skill of simulations [9] [10]. The statistical parameters calculated are listed in **Table 2**. The parameters from USGS and MODIS simulations are similar for the stations T3, EMBRAPA_AM010, EMBRAPA_IRANDUBA. However, for T1, MODIS shows statistical parameters with better quality when compared to USGS. In the case of Skill of Pielke, USGS does not attend the criteria of being representing the atmospheric observed conditions.

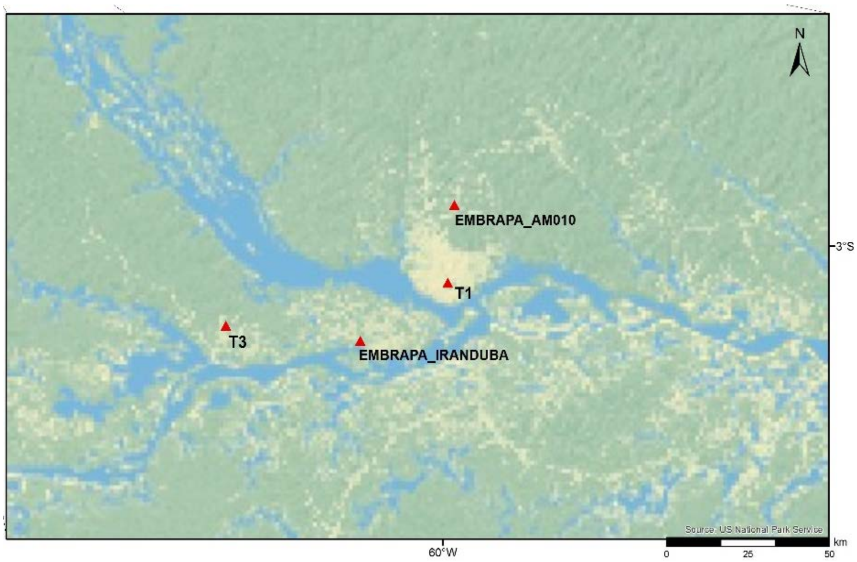

Figure 2. Location of meteorological stations in the study region.

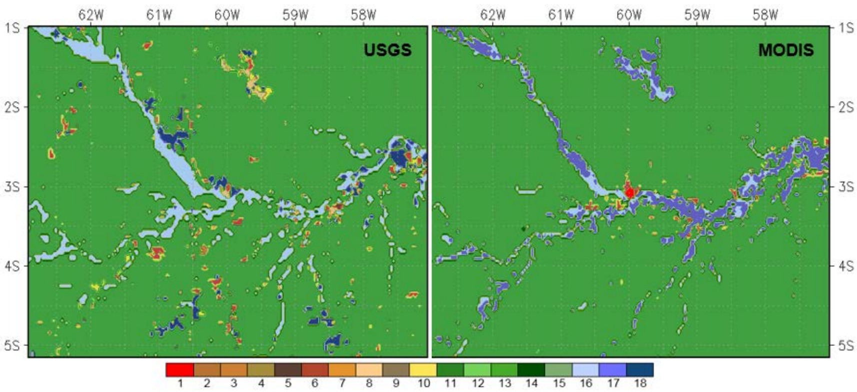

Figure 3. Land use and land cover maps from USGS and MODIS. 1: (red) represents urban and built-up land; 2: dryland cropland and pasture; 3: irrigated cropland and pasture; 4: mixed dryland/irrigated cropland and pasture; 5: cropland/grassland mosaic; 6: cropland/woodland mosaic; 7: grassland; 8: shrubland; 9: mixed shrubland/grassland; 10: savanna; deciduous broadleaf forest; 11: deciduous needeleaf forest; 12: deciduous broadleaf forest; 13: evergreen broadleaf forest; 14: evergreen neddleleaf forest; 15: mixed forest; 16: water bodies; 17: herbaceous wetland; 18: wooded wetland.

Table 2. Comparison of statistical parameters for MODIS and USGS simulations for temperature (˚C).

Stations	Simulations	Obs. Ave.	Obs. Ave.	r	MB	RMSE	S_{pielke}
EMBRAPA_IRANDUBA	MODIS	27.53	26.78	0.92	−0.75	1.55	0.93
	USGS		26.90	0.93	−0.63	1.39	0.80
EMBRAPA_AM010	MODIS	27.26	26.71	0.95	−0.55	2.46	1.18
	USGS		26.68	0.96	−0.58	2.37	1.16
T3	MODIS	27.25	26.81	0.84	−0.44	1.55	0.72
	USGS		26.84	0.87	−0.41	1.41	0.72
T1	MODIS	29.47	29.92	0.92	0.45	2.06	1.80
	USGS		26.93	0.93	−2.55	3.78	3.89

4. Conclusion

The results of this work indicate that differences in files of land cover classification can impact the quality of simulations. The comparison among simulated scenarios by using two traditional databases frequently used in

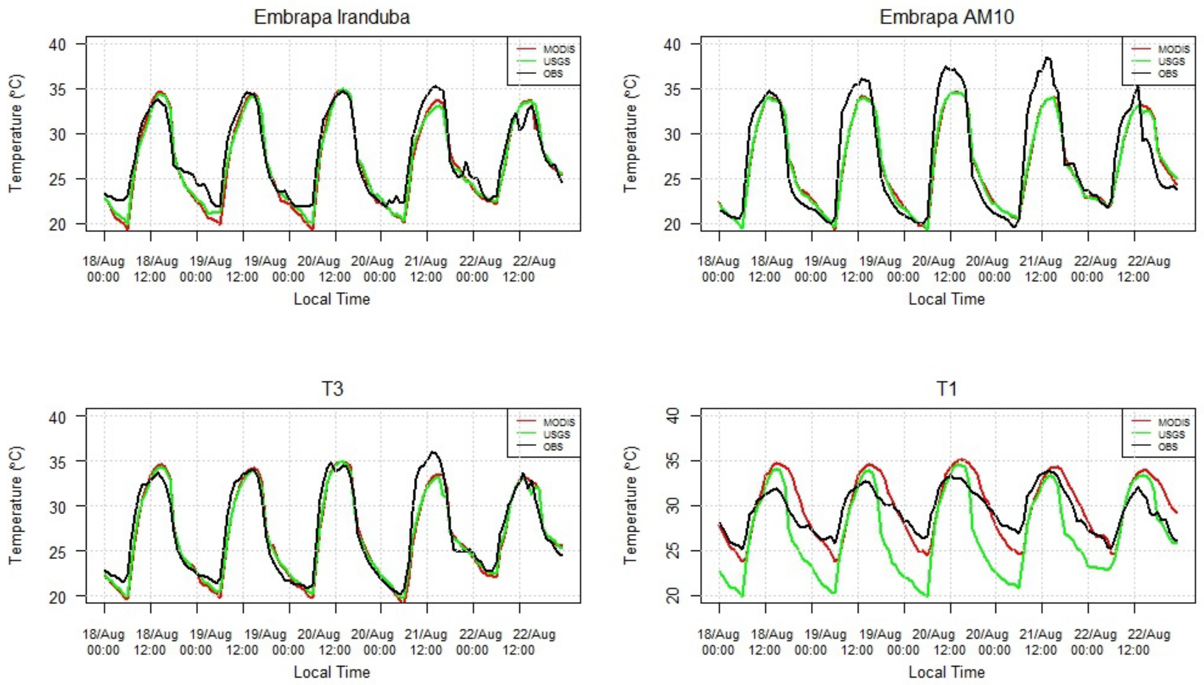

Figure 4. Comparison between simulated and observation temperatures at four meteorological stations. MODIS (red), USGS (green) and measurements (black).

numerical simulations, USGS and MODIS, show different level of agreement with observed meteorological fields, especially temperature. The results show that a more realistic database of land use and cover is fundamental to get good skills in regional atmospheric simulations, especially the temperature in urban areas, which impact straightly on air quality diagnostics.

Acknowledgements

This work received funding support from CNPq (National Counsel of Technological and Scientific Development, process 404104/2013-4), CAPES (Coordination for the Improvement of Higher Education Personnel) and Araucária Foundation.

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