PRECIPITATION SIMULATION USING THE WRF-HYDRO MODEL IN THE MATOPIBA REGION

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Abstract: Hydrological modeling is an important technique for monitoring a region's water resources. The WRF-Hydro model is a powerful system for this type of study and it is attracting more and more attention from the academic community. Studying the hydrology of a region involves several physical components sensitive to the occurrence of precipitation. Thus, to verify whether a hydrological model effectively simulates parameters such as evapotranspiration, surface runoff, or river flow, it must be effective in estimating precipitation. Therefore, this work evaluates the performance of the precipitation simulation of the WRF-Hydro system in the Brazilian region named MATOPIBA, located in the North and north east of Brazil. The simulation presented good correlation with the observed data, showing itself as promising.

Keywords: Hydrological modeling, numerical modeling, WRF-Hydro, MATOPIBA.

SIMULAÇÃO DE PRECIPITAÇÃO USANDO O MODELO WRF-HYDRO NA REGIÃO DE MATOPIBA

Resumo: A modelagem hidrológica é uma técnica importante para o monitoramento dos recursos hídricos de uma região. O modelo WRF-Hydro é um poderoso sistema para esse tipo de estudo e atrai cada vez mais atenção da comunidade acadêmica. Estudar a hidrologia de uma região envolve várias componentes físicas sensíveis à ocorrêcia da precipitação. Assim, para verificar se um modelo hidrológico é eficaz na simulação de parâmetros como evapotranspiração, escoamento superficial ou vazão de rios, é fundamental que seja eficaz na estimativa da precipitação. Portanto este trabalho avalia o desempenho da simulação de precipitação do sistema WRF-Hydro na região brasileira MATOPIBA, localizada no norte e nordeste do Brasil. A simulação apresentou boa correlação com os dados observados, mostrando-se promissora.

Palavras-chave: Modelagem hidrológica, modelagem numérica, WRF-Hydro, MATOPIBA.

1. INTRODUCTION

Water resources are an important source of economic development in Brazil and worldwide. In Brazil, water sources correspond to more than half the capacity of the Brazilian electricity matrix, enhancing the importance of monitoring this resource. One way to monitor water resources, in terms of quantity and water cycle, is through hydrological modeling, which can help in the management of these resources, and which is associated with economic issues such as agriculture and livestock or extreme weather events like floods. Hydrological modeling effectively carries out forecasts, studies on the effects of climate change and land use, water availability analysis, and other applications to support decisions [1].

The coupled hydrological modeling system WRF-Hydro (Weather Research and Forecasting Hydrological modeling system) is an open-source system developed initially by the NCAR (National Center for Atmospheric Research - USA) in collaboration with other entities. The system has been used extensively for various purposes, such as flood forecasting, water resources management, and seasonal watershed monitoring. The WRF-Hydro combines the atmospheric and hydrological model, which can operate coupled or uncoupled [2]. The coupled mode of these models has been shown to be advantageous for precipitation in different areas and for different seasons, especially during convective summer precipitation [3].

The MATOPIBA region is an area shared between the states of Maranhão, Tocantins, Piauí, and Bahia and it is known as the plain land with the greatest agricultural potential in the world [4]. The cultivation of grains stands out as the main agricultural activity. The region still has many conservation units, indigenous lands, and quilombola areas [5], characteristics that show the importance of hydrological monitoring in this territory.

In order to carry out this monitoring, verifying whether variables such as evapotranspiration, surface runoff, or river flow reflect the region's reality, the simulated precipitation must also be in agreement with the real data. Any assessment between amounts of water from various hydrological variables only makes sense if the precipitation inputs are equal or at least comparable with the observations. The evaluation of WRF-Hydro starts from the main force of a hydrological model, precipitation [6].

In this context, this work has as main objective to analyze the performance of the precipitation simulation in a period of intense rains, comparing the model results with the observations in two meteorological stations.

2. METHODOLOGY

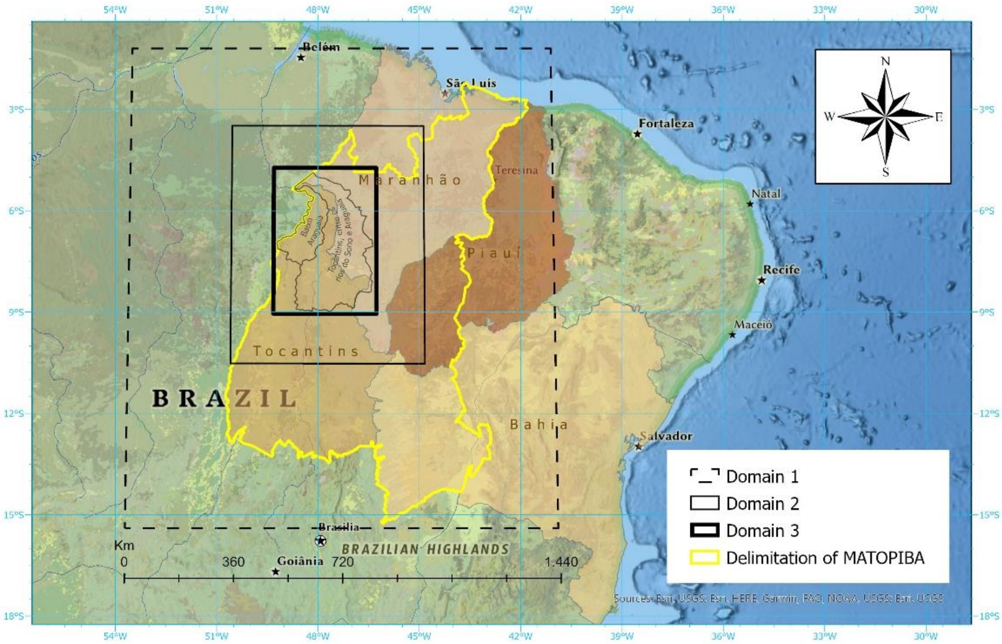
2.1. Study area

The MATOPIBA region is located in the North/Northeast of Brazil and comprehends 337 municipalities in 31 geographical micro-regions, which add up to approximately 73 million hectares. The predominant biome is the Cerrado, which corresponds to around 91% of the territory, followed by the Amazon and Caatinga, 7.3% and 1.7% of the area, respectively. Three hydrographic basins are part of the region: Tocantins River Basin, occupying 43% of MATOPIBA, Atlantic Basin – North/Northeast Section, with 40%, and São Francisco River Basin, with 17%, each of these hydrographic basins being divided into ten sub-basins [7].

The predominant climate is semi-humid tropical, 78% of the territory, with average temperatures above 18°C in all months of the year and dry periods between 4 to 5 months in winter. The eastern limit is characterized by a semi-arid climate, with low humidity and precipitation, about six dry months and high temperatures, b

Figure 1 shows the three aligned domains used in the simulation of the WRF-Hydro model. Domain 1 covers the entire MATOPIBA region, while domain 3, which is the domain of interest and has the highest spatial resolution, occupies two hydrographic sub-basins, Baixo Araguaia and Tocantins, between the Sono and Araguaia rivers, belonging to regions with higher precipitation indices of MATOPIBA.

Figure 1. Study area



2.2. The WRF-Hydro model

The modeling system used in this study is the WRF-Hydro, which was chosen for attracting more and more the attention of the meteorological and hydrological community, it is the most used mesoscale numeric time prevision model hydrological module [2].

The model has been developed to improve the representation of terrestrial hydrological processes relating to the spatial redistribution of surface, ground, and channel waters across the terrestrial surface. It can be operated in two modes: independent or coupled to an atmospheric model. In independent mode, meteorological data obtained by grid input time series are used, and in coupled mode, meteorological data are provided with a frequency dictated by the time interval of the specified terrestrial surface model [8].

In this work, the WRF-Hydro was carried out in fully coupled mode with the WRF meteorological model, which was configured with three nested domains and resolutions of 9, 3, and 1 km, as shown in Table 1.

Table 1. Domain configuration

	Domain 1	Domain 2	Domain 3
Horizontal resolution	9 km	3 km	1 km
Number of cells	155 x 177	211 x 262	337 x 481
Domain size	1395 x 1593 km	633 x 786 km	337 x 481 km

Geoprocessing tools were used in domain 3, resizing the grid from 1 km to 100 m, aiming to create input data from the WRF-Hydro, related to surface, underground, and channel water flows. These data were obtained through the WRF Hydro GIS Pre-Processing Toolkit, developed by NCAR, to use in the geographic information system application ArcGIS, developed and maintained by the American company ESRI (Environmental Systems Research Institute).

The simulation was carried out in March 2020, a period in which there were records of intense rains in the state of Tocantins. The simulation period was 00 h (UTC) on March 9, 2020, until 18 h (UTC) on March 19, 2020, the first two days being considered as spin-up.

The physical parameters used were based on the NCAR Tropical Physics Suite, released by the research center, for real-time forecasts focusing on tropical storms and tropical convection [9].

2.3. Model performance evaluation

In order to evaluate the performance of the WRF-Hydro in terms of precipitation data, the daily results at the closest grid points of two meteorological stations of the National Water and Basic Sanitation Agency of Brazil (ANA) were compared.

The Goiatins stations (7.71° S; 47.32° W and Itacajá (8.39° S; 47.76° W) were chosen, presented in domain 3, within the Tocantins River sub-basin, between the Sono and Araguaia rivers. Figure 2 shows the location of stations with water flows.

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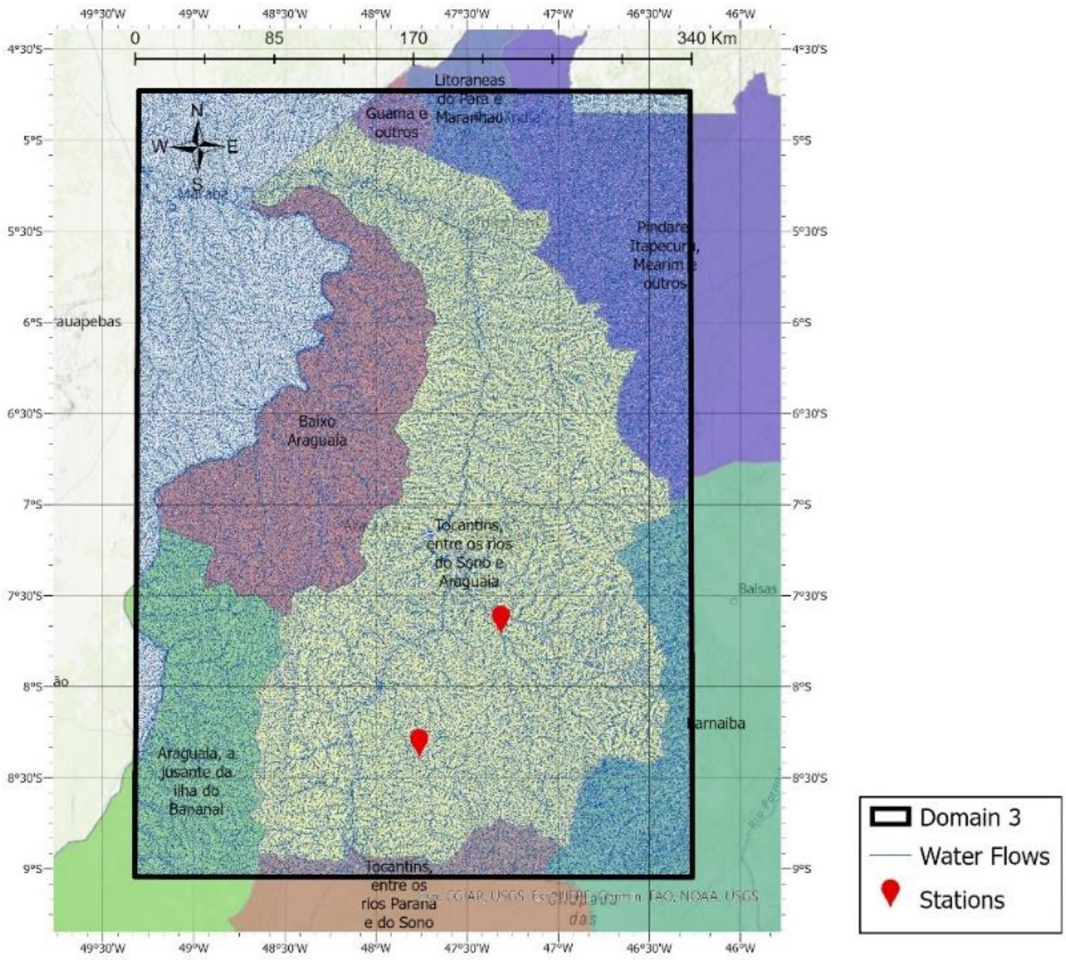
Figure 2. Location of stations with water flows



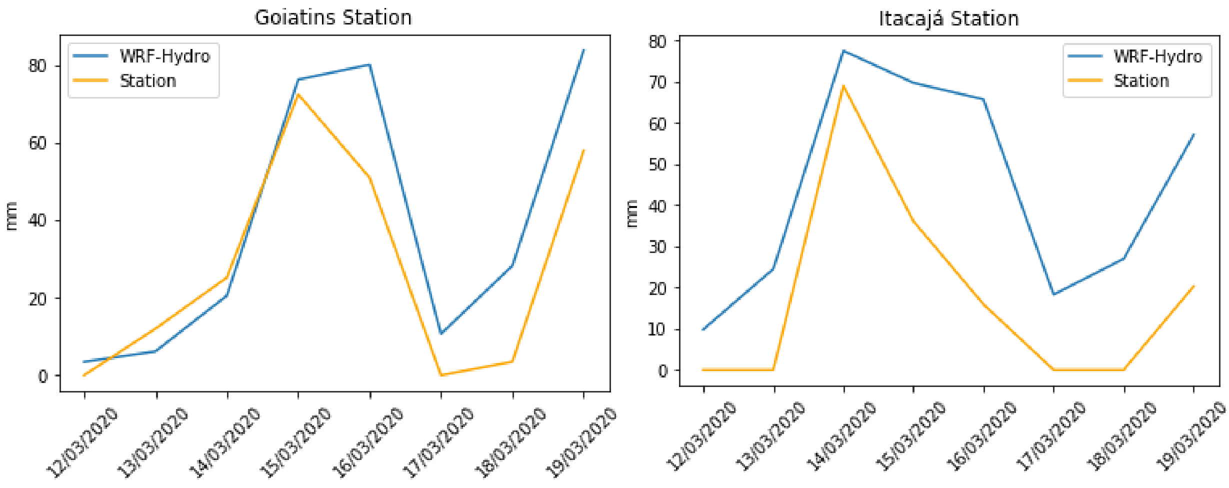
The analysis between the observed and simulated data was done graphically and with some statistical indices, named: the correlation coefficient R, the root mean square error (RMSE), and the BIAS estimator, which are widely used to evaluate forecast models [10].

Pearson's correlation coefficient (R) describes the degree of collinearity between simulated and measured data, ranging from -1 to 1. If R = 0, there is no linear relationship. If R is close to 1 or -1, it indicates a strong positive or negative linear relationship. The RMSE, on the other hand, expresses systematic and random errors, consisting of the square root of the mean squared errors. It is one of the most commonly used error rate statistics. The lower the RMSE, the better the model's performance. Finally, BIAS measures the average tendency of simulated values to be larger or smaller than the measured data [10, 11].

3. RESULTS AND DISCUSSION

The month of March 2020 had a high amount of rainfall observed in the study region, reaching a daily total of 72.5 mm at the Goiatins station and 69 mm at Itacajá. Figure 3 shows the time series from 12/03/2020 to 19/03/2020 of the daily rainfall of the data observed in the two ANA stations and the data obtained with the simulation of the WRF-Hydro.

Figure 3. Daily precipitation simulated at WRF-Hydro and observed at ANA stations



In both analyses, the simulated precipitation data overestimated the precipitation values recorded in the mentioned pluviometric stations. However, there is apparently a considerable correlation between the WRF-Hydro and season curves, indicating growth and decrease of data in practically the same interval of days. This good correlation is verified through the Pearson correlation coefficient, which obtained a value of 0.92 at the Goiatins station and 0.84 at the Itacajá station. These values, considering other works presented in the literature that evaluated the performance of precipitation simulations using the WRF model [10, 12, 13], are considered very good.

The BIAS and RMSE coefficients did not present values as satisfactory as the R correlation. The BIAS proves a greater overestimation of the simulated data concerning those observed at the Itacajá and Goiatins station, with values of 26.03 and 10.89, respectively. The RMSE value at Itacajá station was 29.13 and at Goiatins 17.06. Despite being a smaller number, the latter is still not an error considered adequate [14]. However, these simulations are initial and still need further analysis. For example, tests with other parameterizations based on studies carried out with the WRF and WRF-Hydro in regions with climatic characteristics similar to MATOPIBA have already started.

4. CONCLUSION

The preliminary results of the simulations with the WRF-Hydro model are encouraging. This model represents state-of-art hydrological modeling and is a fundamental step for hydrological assessments, both in the MATOPIBA region and in other regions of Brazil. Despite the differences between the results measured at the stations and those simulated, they can be considered very good given the complexity involved. In this sense, the following steps will explore other parameterizations and a longer simulation time (for example, one year of data), both in the precipitation variable and in the flow of the rivers under analysis.

Acknowledgments

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