Modeling Evapotranspiration and Temperature in the Amazon Basin Using the WRF Model

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The Amazon rainforest has been significantly impacted by increased deforestation and a temperature rise of 2.2°C. These factors and climate change disrupt the natural interaction cycle between the forest and the climate, affecting the global moisture flow. In this context, the present study aims to simulate meteorological variables, specifically evapotranspiration and temperature, in the Amazon Basin using the WRF (Weather Research and Forecasting) mesoscale model. The simulation covered the year 2021 with a spatial resolution of 9 km. This allowed for an evaluation of the spatial distribution of temperature and evapotranspiration throughout the year, providing insights into the behavior of these variables in the region. The simulations were satisfactory, underscoring the model's potential to support environmental studies and analyses on the Amazon Basin. It was found that April, October, and November exhibited the highest temperature values, averaging between 36-42 °C. In contrast, the lowest temperatures were recorded in June and July, with average values ranging from 6-18 °C.
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Globally, extreme meteorological phenomena such as heat waves, droughts, and intense rains have become more frequent over the past 20 years [1,2]. Alongside the Pacific Ocean, the Amazon rainforest is a significant source of moisture in the global atmosphere, playing a crucial role in regulating the global climate system.

However, increased deforestation has significantly impacted the Amazon, with 19% of the area now deforested [3]. Other issues include land grabbing, agricultural expansion, fires, forest degradation, and a temperature rise of 2.2 °C [4].

These factors, coupled with climate change, disrupt the natural interaction cycle between the forest and the climate, affecting the global flow of moisture [5,6]. Given this scenario, the pursuit of sustainability in the Amazon has driven the development of systemic studies across various knowledge domains and at different spatial and temporal scales. To address these challenges, high-resolution atmospheric-hydrological models are emerging as a promising approach to understanding the dynamics of a river basin. The primary model of this type, the Weather Research and Forecasting (WRF) model [7], has been extensively studied and optimized to provide an improved numerical tool for global water resource planning and assessing the impacts of climate change on regional hydrology. In this context, the present study aims to simulate meteorological variables, specifically evapotranspiration and temperature, in the Amazon Basin for the year 2021 using the WRF mesoscale model with a spatial resolution of 9 km, incorporating land cover and use data from MapBiomas.

Materials and Methods

The study area for this work corresponds to the Amazon Basin (Figure 1). The simulations were conducted using land use and occupation data from Collection 7 of the MapBiomas Project (https://MapBiomas.org/), which was processed using the Raster calculator of QGIS 3.26 software for 2021 and 1985. The analysis of this data is crucial as it allows the model to integrate changes in land use and occupation over time accurately. The simulations were carried out using WRF version 4.2.0, initialized at 0000 UTC and extending to 1800 UTC from January to December 2021 for the region under study. The initial and boundary conditions used in the simulations were sourced from the global atmospheric model GFS (Global Forecast System) from NCEP (National Center

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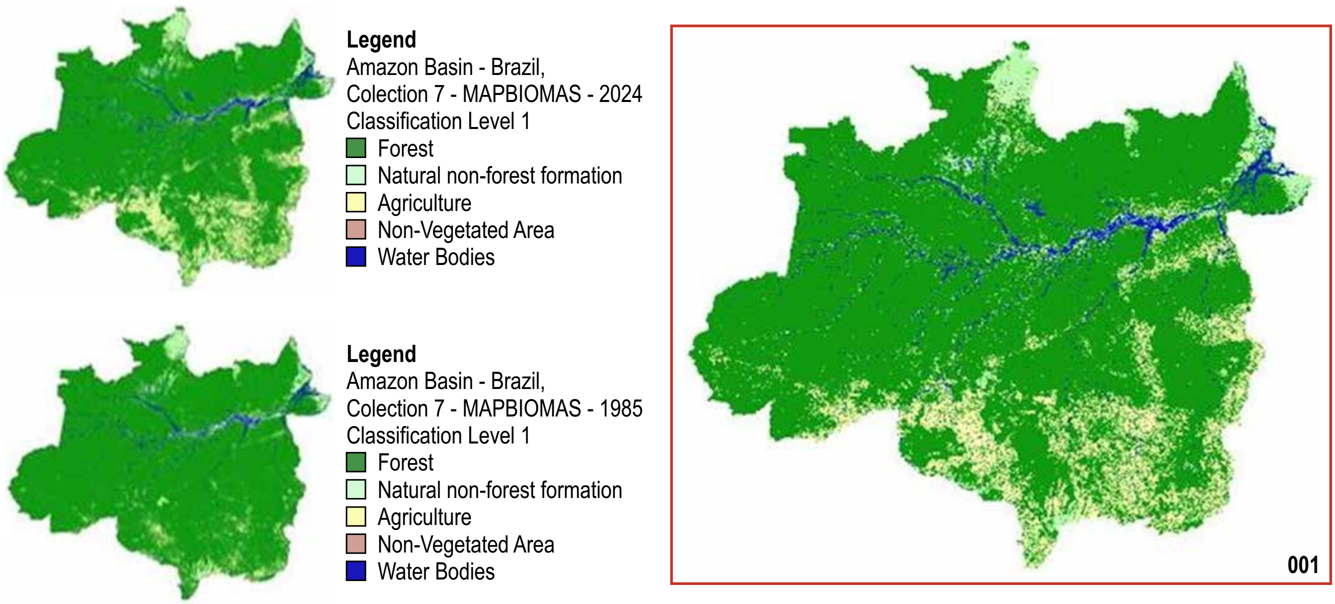
Figure 1. Changes in land use and occupation in the Amazon Basin in the years 1985 and 2021.



for Environmental Prediction), with a horizontal resolution of 0.25° x 0.25° and a temporal resolution of 6 hours. The model was configured with a grid resolution of 9 km (336x285) and 50 vertical levels encompassing the Amazon Basin [5] (Figure 1).

The physics options adopted and left unchanged for all simulations were as follows:

- Microphysics: WRF Single-Moment 6-class scheme
- Cumulus: Grell-Freitas scheme Boundary Layer Parameterization: Mellor-Yamada Nakanishi and Niino Level 2.5 PBL.
- Radiation: RRTMG for both shortwave and longwave radiation.
- Land-Surface Model: Noah Aerosol Interactions with Radiation: Parameterized following Ruiz-Arias and Thompson's water/ice-friendly approach.

By incorporating detailed land use and occupation data, the WRF model can more accurately reflect the environmental dynamics of the Amazon Basin. This allows for a more precise simulation of meteorological variables, providing valuable insights for environmental studies and policy-making.

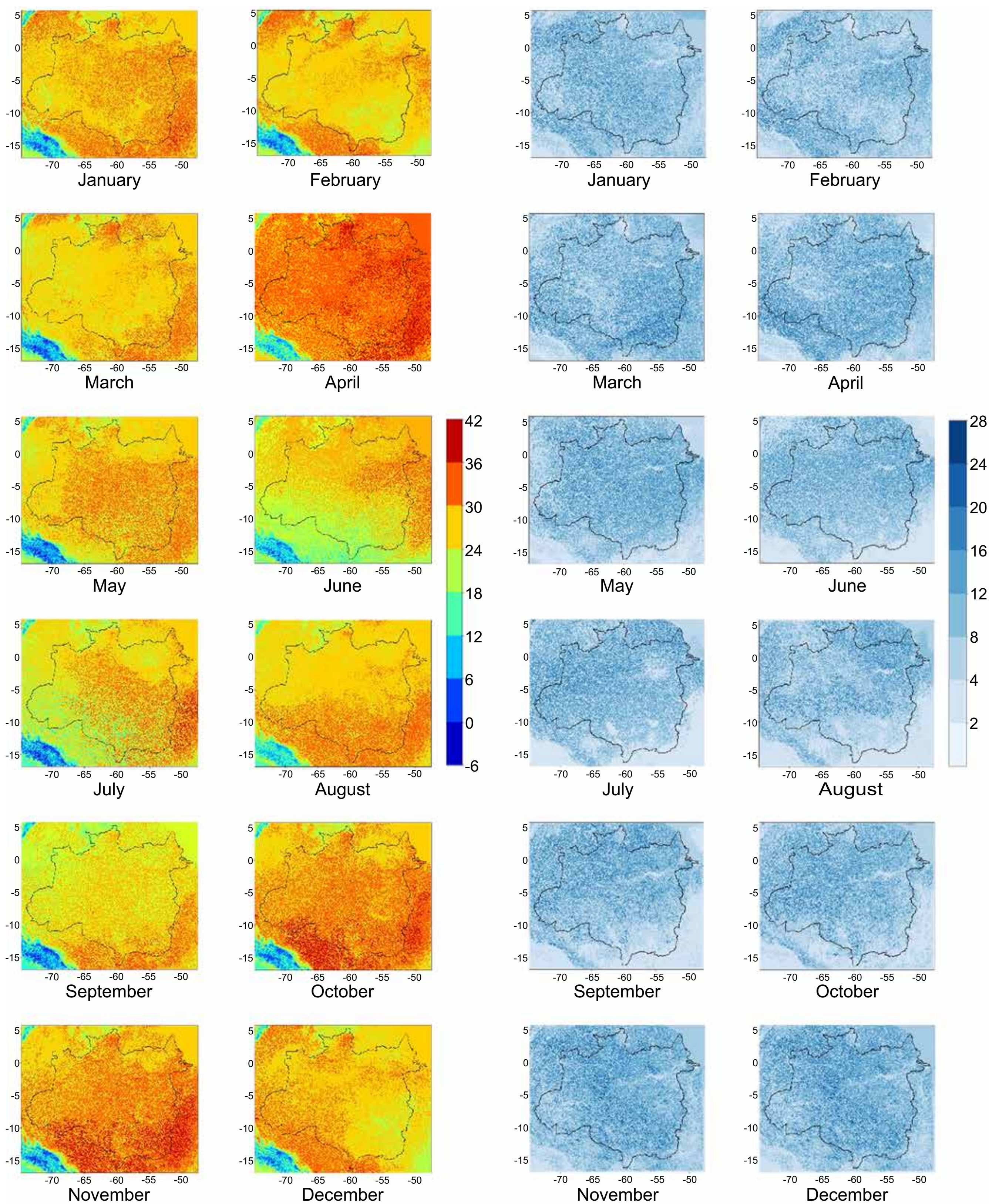
Results and Discussion

Figure 2 presents temperature and evapotranspiration (ET) maps generated from numerical modeling for 2021. Due to the vast expanse of the Amazon Basin, there are pronounced spatial gradients of hydrometeorological variables, resulting in significant spatial variations in temperature and ET.

The temperature maps reveal that April, October, and November experienced the highest temperature values, with averages ranging between 36-42 °C, which were more evenly distributed across the region. In contrast, the lowest temperatures occurred in June and July, with average values ranging from 6-18 °C. Notably, the highest temperatures were consistently recorded in the basin's southern part throughout most of the year.

Regarding ET, the monthly averages are well-distributed across the basin. The increase in ET is primarily related to increases in solar radiation and temperature, the two main variables influencing ET variability in the Amazon region. This relationship is evident when comparing the monthly average ET values with the monthly average temperature values during the simulated period. Similar results for the estimation of ET

Figure 2. Map of monthly average temperature (on the left) and evapotranspiration (on the right).



and temperature variables in the region have been reported in previous studies [6-10].

The spatial distribution and variability of temperature and ET across the Amazon Basin underscore the region's complex climatic dynamics. The findings highlight the importance of using high-resolution models to capture these variations accurately, which is crucial for environmental studies and climate impact assessments.

Conclusion

This initial study aimed to analyze the spatial distribution of temperature and evapotranspiration (ET) in the Amazon Basin, highlighting the potential of the WRF model to support environmental studies and analyses focused on the region. Additionally, the work sought to address the current dynamics of land use and occupation in the Amazon, offering a contemporary perspective on these changes and their impacts. Future research will be dedicated to exploring potential correlations between deforestation and ET patterns and other meteorological variables, focusing on areas that have undergone intense changes in land occupation. Furthermore, a detailed hydrological analysis will be conducted in the Manaus region using the hydrological module of the WRF model to understand local water dynamics better. Additionally, changes in land use and occupation between 1985 and 2021 will be analyzed through simulations to identify environmental impacts in the Amazon Basin during this period of significant change. This study underscores the importance of using advanced modeling techniques to understand the complex interactions between land use, climate, and hydrological processes in the Amazon Basin. Continued research will provide valuable insights for sustainable management and conservation efforts in this critical region.

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References

1. IPCC. Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, 2021.
2. Marengo JA. et al. Increased climate pressure on the agricultural frontier in the Eastern Amazonia–Cerrado transition zone. Scientific reports 2022;12(1):457.
3. Salomão CS. et al. Amazônia em chamas: desmatamento, fogo e pecuária em terras públicas. Nota Técnica, n. 8, p. 7-8, 2021.
4. Lovejoy TE, Nobre C. Amazon tipping point Sci. Adv. 4 eaat2340. 2018.
5. Vieira CS et al. Evaluation of the physical sensitivity of the wrf-hydro model in the simulation of rainfall in manaus-am using different sets of parametrizations. 2022.
6. Sierra JP et al. Deforestation impacts on Amazon-Andes hydroclimatic connectivity. Climate Dynamics 2022:1-28.
7. Skamarock WC et al. Description of the Advanced Research WRF Version 4. National Center for Atmospheric Research/Boulder, Colorado, USA, 2008.
8. Gomes WWE. Modelagem espaço-temporal da evapotranspiração de referência na Bacia Amazônica em um cenário de crescimento na emissão de gases do efeito estufa. Universidade Federal de Minas Gerais. Instituto de Geociências, 2020.
9. Fernandes VR. Modelagem espaço-temporal da evapotranspiração de referência na Bacia Amazônica em um cenário de crescimento na emissão de gases do efeito estufa. Dissertação de Mestrado. Universidade Federal de Alagoas. Instituto de Ciências Atmosféricas, 2012.
10. Gomes WWE et al. Simulação dos impactos das mudanças climáticas globais na evapotranspiração de referência da bacia amazônica brasileira. Revista Brasileira de Climatologia 2021;28:450-470.