EVALUATION OF THE EC-EARTH3-VEG CLIMATE MODEL IN REPRODUCING THE EVOLUTION OF MAXIMUM AND MINIMUM AIR TEMPERATURES IN BRAZIL

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Introduction

The Sixth Report of the Intergovernmental Panel on Climate Change (IPCC, 2023) highlights a substantial rise in global surface temperatures between 2011 and 2020. This upward trend is related to shifts in observed climate patterns, that may lead to biodiversity loss, decreased agricultural outputs, changes in water resource availability, and impacts on human health. In Brazil, these factors carry implications for the nation's economy and energy security, given the strong correlation between domestic energy supply and Gross Domestic Product (GDP) (MME; EPE; 2023). Additionally, it should be noted that the growth of agricultural activity by 15.1% between 2022 and 2023 directly influenced the country's GDP growth performance in the last year (IBGE, 2024).

Considering these aspects and the potential impacts of increasing global surface temperature on Brazil, we assessed the ability of the EC-Earth3-Veg model to reproduce the evolution of air temperatures at 2 meters during the historical period. Our aim was to ascertain the model's suitability for future analyses considering the Shared Socio-economic Pathway (SSP) climate change scenarios.

Methodology

We used historical temperatures at 2 meters from the EC-Earth3-Veg model, part of the Coupled Model Intercomparison Project Phase 6 (CMIP6), and compared it with ERA5 reanalysis data. Applying a mask, we extracted both datasets for coordinate points within Brazil's geographical boundaries. Subsequently, we examined the data across four time intervals delineated by the IPCC Atlas: 1850-1900, 1961-1990, 1981-2010, 1986-2005, and 1995-2014.

To obtain the final results, several steps were necessary:

- Interpolating the CMIP6 data to the ERA5 grid;
- Obtaining maximum and minimum temperatures for each time interval;
- Calculating temperature differences between the CMIP6 and ERA5 datasets;
- Obtaining difference values for each season of the year;
- Plotting the differences in a map to visualize warming and cooling patterns;
- Calculating average maximum and minimum temperatures for each season;
- Obtaining values for the five main regions of Brazil;
- Plotting the results in a bar graph to observe the variations across each region;

Results

The figures depict the results obtained for the 1981-2010 interval, serving as a reference for the analysis conducted for the historical period. This interval is widely employed in climate analysis due to its representation of a recent 30-year period, offering a stable and comprehensive perspective on long-term climate trends.

Figures 1 and 2 illustrate the climatological differences obtained for Brazil concerning the maximum and minimum temperatures. They provide insight into the primary areas where the EC-Earth3-Veg model produced a warming trend.

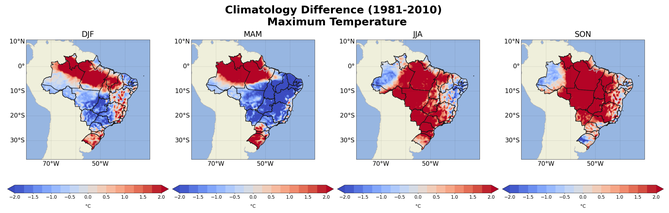

Figure 1: Spatial distribution of differences in maximum temperatures at 2 meters (°C) between EC-Earth3-Veg and ERA5 for the period 1981-2010. The seasonal quarters are delineated as follows: DJF (December-January-February), MAM (March-April-May), JJA (June-July-August), and SON (September-October-November).

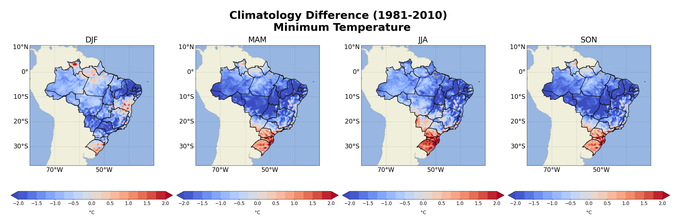

Figure 2: Spatial distribution of differences in minimum temperatures at 2 meters (°C) between EC-Earth3-Veg and ERA5 for the period 1981-2010.

Figures 3 and 4 display the climatological differences obtained for each region of the country. They enable us to identify where the model either overestimated or underestimated the temperature, as well as the seasons with the highest differences.

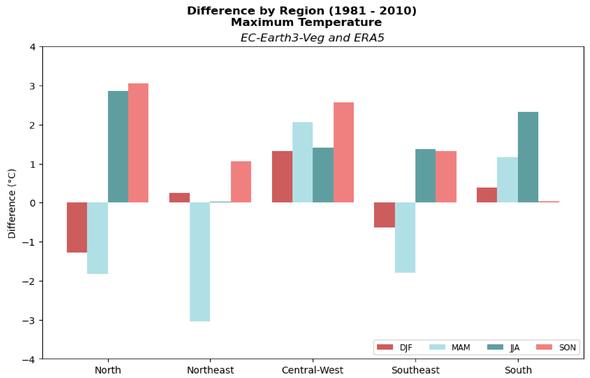

Figure 3: Average difference in maximum temperatures at 2 meters (°C) between EC-Earth3-Veg and ERA5 for each region of Brazil during the period 1981-2010.

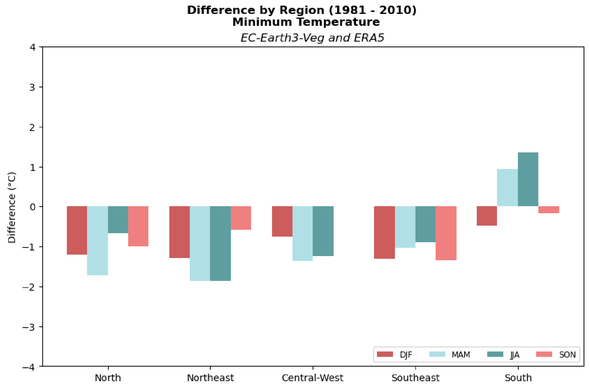

Figure 4: Average difference in minimum temperatures at 2 meters (°C) between EC-Earth3-Veg and ERA5 for each region of Brazil during the period 1981-2010.

Discussion and Conclusion

EC-Earth3-Veg successfully reproduced the historical climatology of Brazil but displayed disparities compared to ERA5 across all observed periods. Distinct regional and seasonal patterns were identified, suggesting potential limitations in the model's horizontal resolution, particularly in capturing atmospheric characteristics in the South region. Future plans include addressing biases to mitigate systematic errors and replicating these findings with other models for further validation.

Some consistent findings among the examined periods include:

- Warmer temperatures in northern regions during summer and autumn;
- Warmer temperatures in winter and spring in North, Central-West, and Southeast;
- Cooler temperatures in the fall in the Northeast and Central-West regions.

Key findings for the 1981-2010 interval are as follows:

- Higher maximums in summer in the North region and parts of the Northeast and South, although EC-Earth3-Veg underestimated temperatures in the North;
- Elevated maximum temperatures in winter and spring throughout the country, with warming trends evident in the Central-West, South, and part of the Southeast;
- Underestimation of minimum temperatures during winter and spring;
- A warming trend observed in the extreme south of Brazil in winter.

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