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Scalar interaction in a mangrove environment: an analysis of climate attributes at the regional and microclimatic scale

Interacción escalar en un ambiente de manglares: un análisis de los atributos climáticos a escala regional y microclimática

Interação escalar em ambiente de manguezal: uma análise dos atributos do clima na escala regional e microclimática

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Abstract

Mangroves are transitional ecosystems, where the river environment meets the sea. It develops in the intertropical belt of the globe, so that this environment demands conditions of high average temperatures and total rainfall for its development. Mangrove vegetation acts as a climate attribute control, creating a specific microclimatic condition below and above the canopy. It is from the difference between the two environments that the multiscale study of the climate is based, where the vegetation and the latter influence the microclimatic environment within the forest by the regional atmospheric dynamics that act above the canopy. It is from this relationship between the climate scales that the multiscale climate analysis in a mangrove environment is structured.

Keywords: mangrove, microclimate, mesoclimate, atmospheric dynamics, canopy.

Resumen

Los manglares son ecosistemas de transición, donde el entorno fluvial se encuentra con el mar. Se desarrolla en el cinturón intertropical del globo, por lo que este ambiente demanda condiciones de altas temperaturas medias y precipitaciones totales para su desarrollo. La vegetación de manglares actúa como un control de atributos climáticos, creando una condición microclimática específica por debajo y por encima del dosel. Es a partir de la diferencia entre los dos ambientes que se basa el estudio multiescala del clima, donde el ambiente microclimático dentro del bosque está influenciado por la vegetación, y este último por la dinámica atmosférica regional que actúa sobre el dosel. Es a partir de esta relación entre las escalas climáticas que se estructura el análisis climático multiescala en un ambiente de manglar.

Palabras clave: manglar, microclima, mesoclima, dinámica atmosférica, dosel

Resumo

Os manguezais são ecossistemas de transição, onde o ambiente fluvial encontra o mar. Se desenvolve na faixa intertropical do globo, de modo que este ambiente demanda condições de elevadas temperaturas médias e totais pluviométricos para seu desenvolvimento. A vegetação do manguezal atua como um controle do atributo climático, criando uma condição microclimática específica abaixo e acima do dossel. É a partir da diferença entre os dois ambientes que se baseia o estudo multiescalar do clima, onde o ambiente microclimático dentro do bosque sofre influência da vegetação, e esta da dinâmica atmosférica regional que atua acima do dossel. É a partir desta relação entre as escalas do clima que se estrutura a análise multiescalar climática em ambiente de manguezal.

Palavras-chave: manguezal, microclima, mesoclima, dinâmica atmosférica, dossel.

Introduction

The mangrove ecosystem represents a transitional environment between the terrestrial and marine environments, where the river environment meets the sea. Therefore, this ecosystem is rich from both abiotic and biotic points of view, so it is of fundamental importance for the development of marine and terrestrial species. Its development across the globe is limited to the tropical and subtropical zone, so that it presents specific conditions for its full development (Schaeffer-Novelli et al., 1995).

The microclimatic study of the mangrove swamp located in Barra do Ribeira-Iguape/SP allows us to understand the influences of atmospheric dynamics and the

environment on climate attributes, as well as how changes in this ecosystem influence such factors from a microclimatic point of view.

Therefore, the current work has as its first objective the microclimatic analysis based on data obtained from a meteorological station installed in the study area, in line with the analysis of regional atmospheric dynamics through synoptic charts, which allows us to understand the relationship between the mesoclimatic and microclimatic scales (Ribeiro, 1993).

Lima (2014) addresses the mangrove in its entirety as a landscape, where climatic characteristics and their controls interact with each other, composing a mosaic of attributes such as precipitation, incidence of solar radiation, wind direction and speed, air temperature and humidity are controlled mainly by factors of atmospheric dynamics and mangrove vegetation, and also considered that these climatic attributes are of fundamental importance for the analysis of scalar interactions (meso and micro) in the mangrove forest. For this author, aspects such as vegetation structure (species, canopy geometry and height); tides (as they are a fundamental factor for the cycle of matter and decomposition of mangroves); as well as meteorological systems, highlighting the role of extratropical fronts, cyclones and anticyclones as weather changers and climate regulators in the study area in question. For the work in question, the author's formulations are considered based on the climatic attributes of air temperature, which provides a theoretical framework, as well as those of other authors such as Monteiro (1973), Galvani et al (2022), Tarifa (2004), in order to carry out detailed studies and analyses on the attributes in question. Nevertheless, the postulates of Borsato (2016) for the analysis of air masses acting in Brazil, as well as the interpretation of synoptic charts, which allow visualizing atmospheric dynamics in time and space.

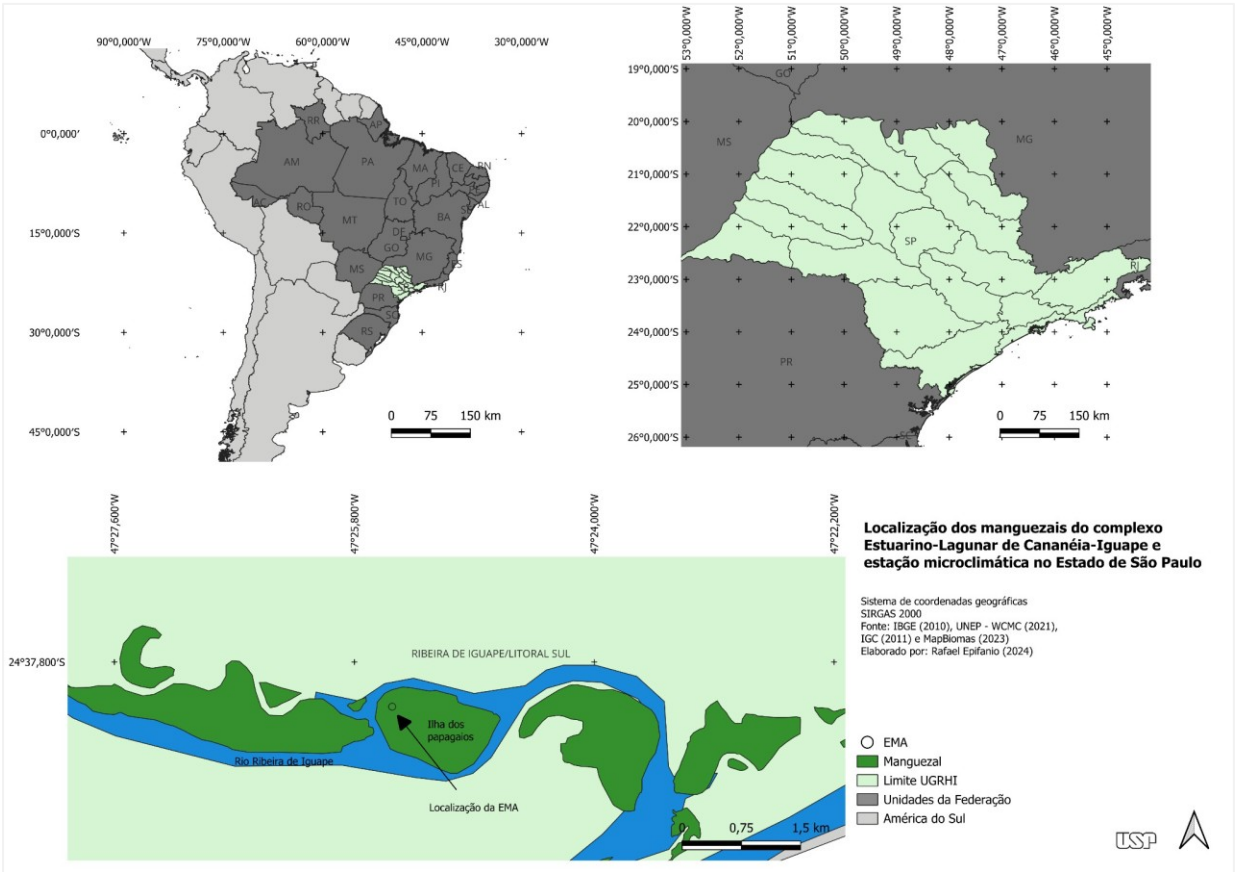
Thus, the climatic analysis carried out in this article presupposes the interaction between climate scales, so that the air temperature records in the

mangrove microclimate will be associated with the air masses acting in a given time and space.

Materials and methods

Two main methods were used to collect data: the first involves the analysis of data collected from the meteorological station installed in Barra do Ribeira-Iguape/SP (Lima et al, 2013; 2018); the second involves the analysis of synoptic charts to understand the atmospheric dynamics in the period and region studied. The data from the synoptic charts were obtained from https://www.marinha.mil.br/chm. The images were obtained at 00 GMT and 12 GMT.

Map 1 - Location of the mangrove swamp of the Cananéia-Iguape coastal system and the microclimatic station.



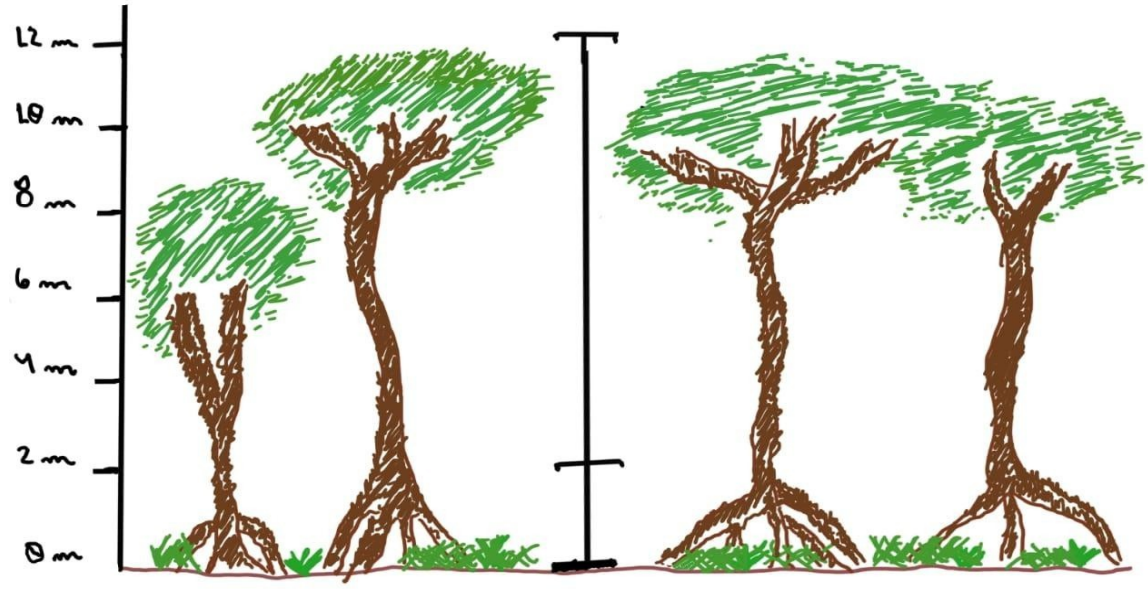
Source: Lima (2024)

The meteorological station was installed in the mangrove in February 2008, containing two sets of equipment, with sensors for air temperature and relative humidity, soil/water temperature, global solar radiation, wind direction and speed,

and rainfall. These are essential for studying and monitoring the ecosystem's microclimate (Lima et al. 2018). In this study, only the air temperature attributes are analyzed.

It is considered that the differences in climatic attributes within the canopy (air temperature, relative humidity, precipitation, global solar radiation, wind direction and speed) are mainly influenced by the plant structure of the mangrove, considering its height, canopy, plant species, leaf area, density, canopy opening, as well as other ecophysiological aspects of the mangrove forest that end up inferring the climatic attributes, especially the incidence and interaction of solar radiation in the ecosystem environment in question (Lima, 2014).

Diagram 1- Installation of the microclimatic tower located at – Papagaios Island – Barra do Ribeira – Iguape/SP



Source: Lima (2024)

The tower installation shown above is divided into two parts, one installed 2 meters above the surface, and the other 12 meters. This difference allows us to analyze the influence of the forest canopy on the climatic attributes, so that the 2-meter station is located below the treetops, while the 12-meter station is located above them, with recordings every 10 minutes.

The climatic analysis considers the temperature records (minimum, average and maximum) of the meteorological station for the year 2018, together with the synoptic charts prepared by the Brazilian Navy. For the regional scale, the postulates of Monteiro (1973), Novais (2019, 2023) and Galvani et al (2022) were considered, in which they formulate the regional climate of the study area in question, in order to categorize the climatic characteristics for the purpose of analyzing the influences of air masses on the production of weather in the region and their influence on the measured climatic attributes.

The surface synoptic charts were obtained between 2008 and 2019. The methodology for reading and interpreting the charts was based on the work of Borsato (2016). The author explains the importance of synoptic charts, their symbology, and how to understand regional atmospheric dynamics from their reading.

To analyze the scalar interaction between the microclimate and the regional scale, July 8, 2018, was selected because it presented a significant drop in air temperature records, in order to investigate the atmospheric system and air mass acting in the study area.

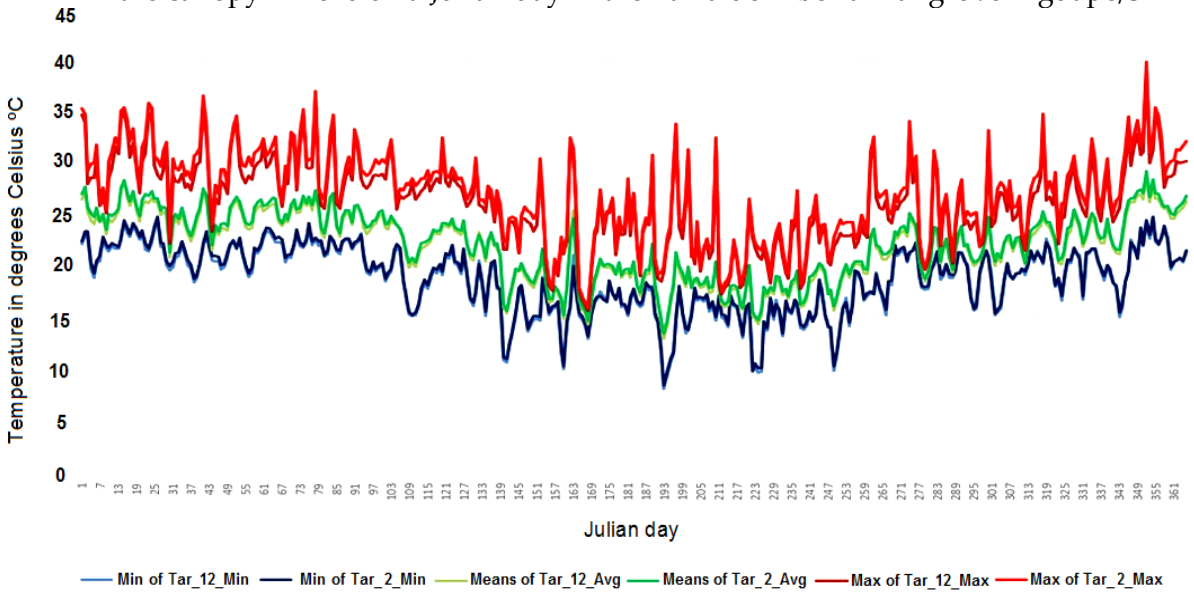
The graphical analysis of temperatures (minimum, average, and maximum) is considered together with the synoptic analysis of extreme records of the respective date, in order to allow the multiscale understanding of the phenomena and the measurement presented.

Results and discussion

To analyze the minimum, average and maximum temperatures in the mangrove environment, based on data from the Iguape meteorological station, the absolute minimum temperature, the absolute maximum temperature and the average temperature were considered. For the annual study of air temperatures, the year 2018

was selected in the mangrove forest, as it presented temperatures above the expected average in relation to records from other years in the database (2008 to 2019).

Graph 1 - Maximum, average and minimum air temperature above (12m) and below (2m) the canopy in 2018 on a Julian day in the Barra do Ribeira mangrove - Iguape/SP



Source: Lima (2024)

Graph 1 shows the maximum, average and minimum temperatures recorded at 12 meters and 2 meters above the surface throughout 2018 in Iguape. The seasonality characteristic of this latitude can be observed, with higher temperatures in the summer, milder in the fall and spring and lower in the winter.

The average temperatures recorded were around 27°C and 22°C in the summer and fall, 15°C to 21°C in the winter and 19°C to 24°C in the spring. Maximum temperatures are more prominent in the summer, around 27°C to 36°C, decreasing in the fall and winter with records around 23°C and 33°C and increasing again at the beginning of the spring, recording temperatures around 27°C to 34°C. Minimum temperatures are prominent in winter, with temperatures around 17°C and 14°C, with some days recording temperatures below 12°C.

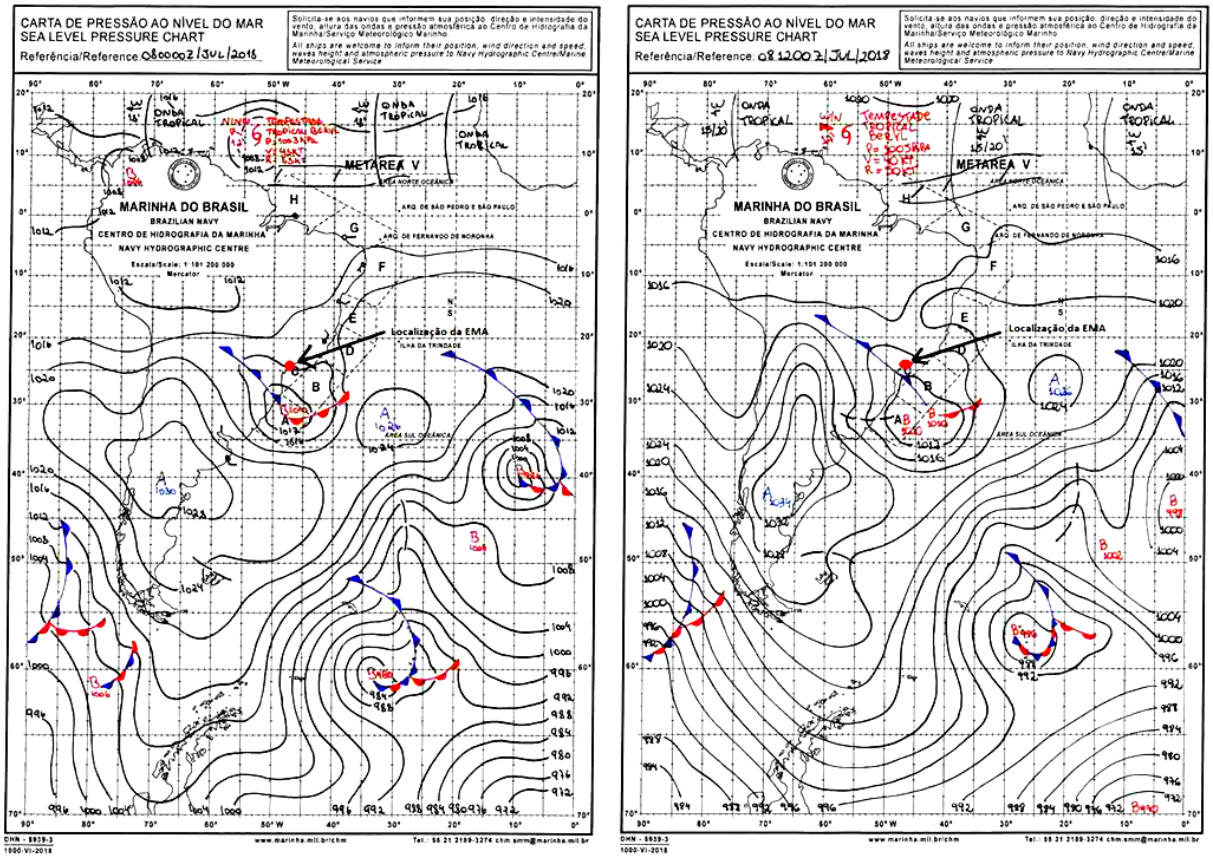
Temperatures above 36°C can be observed for the absolute maximum temperatures on February 10, March 19 and December 18, with records of 36.3°C, 36.7°C and 39.5°C, respectively. For absolute minimum temperatures, the days of

May 21, June 9, July 12, August 12 and September 6 stand out, with records of 11.1°C, 10.4°C, 8.6°C, 10.2°C and 10.4°C, respectively.

Finally, a drop in temperature was observed between January 29 and 30, February 10 and 13, March 19 and 22, June 1 and 5, June 11 and 17, July 8 and 11 (the period selected for analysis of the synoptic charts), July 29 and 30, August 25 and 26, and October 3 and 6. This considerable variation in the records is associated with the passage of a frontal system or atmospheric system of a regional nature with physical characteristics different from those acting in the analyzed study area.

It is possible to observe that the measurements below the canopy (2 meters) present a slight thermal amplitude when compared to the records above the canopy (12 meters). This amplitude is more evident in the maximum temperature record, where the measurements at 2 meters present up to 1.0°C of variation when compared to the records above the canopy. This factor may be related to changes in the leaf area (LA) and leaf area index (LAI) of the canopy, which infers the incidence of global radiation on the surface below the vegetation. If this index decreases, it means a higher incidence of radiation, therefore greater heat generation within the canopy environment (2 meters), inferring higher temperatures compared to the environment above the canopy, at 12 meters (Lima, 2009). According to Lima et al. (2021), the mangrove forest where the EMA was installed has been showing changes in the canopy, reflecting historical environmental changes present in the region.

Panel 1- Surface synoptic charts for July 8, 2018 at 00 GMT (left) and 12 GMT (right).



Source: Brazilian Navy (2018) Adapted by Lima (2024)

The synoptic charts above allow us to visualize the atmospheric dynamics in South America on July 8th at 00 GMT and 12 GMT. It is possible to identify the passage of a frontal system in the south-southeast of the country, originating from medium and high latitudes in southern South America, associated with the formation of an extratropical cyclone to the southeast, in the South Atlantic (Borsato, 2016).

The minimum temperatures recorded around 15.0°C and 9.0°C between July 8th and 13th are associated with the passage of this system. July 8th presents minimum temperature records between 18.0 and 17.0°C, decreasing over the course of the 9th, 10th, 11th, 12th and 13th. July 12th has the lowest values recorded with 8.2°C at 12 meters and 8.6°C at 2 meters.

Final Considerations

The microclimate monitored by the meteorological station installed and located on – Ilha dos Papagaios – Barra do Ribeira – Iguape/SP, allowed the recording of climatological data between the years 2008 to 2019.

The year considered for analysis in this work (2018) presents expected temperature records for the region, with averages between 15.0°C and 26.0°C. The seasonality stands out, where in the hot summer season, there are maximum temperatures above 30.0°C throughout the months of December and January. In the cold winter season, there are minimum temperatures below 15.0°C throughout the months of July and August.

Measurements above and below the canopy show differences in records. It is noted that temperatures at 2 meters, below the tree crowns, present slight thermal amplitudes greater than the environment at 12 meters, above the tree crowns. This difference occurs due to changes in leaf area (FA) and leaf area index (LAI), mainly due to changes in the vegetation of the mangrove where the EMA was located. The change in the canopy promotes a greater incidence of radiation below the vegetation, promoting heat generation and higher temperatures below the canopy (2 meters) compared to above the canopy (12 meters).

Finally, climate analysis integrating meso and micro scales allows understanding the interaction between atmospheric dynamics and records observed in the study area. Synoptic charts allow observing regional atmospheric circulation that ends up generating specific microclimate conditions. Thus, an intrinsic relationship is observed between atmospheric conditions and the observed microclimatic records.

References

BORSATO, Victor da Assunção. **A dinâmica climática do Brasil e massas de ares** / Victor da Assunção Borsato. - 1. ed. - Curitiba, PR: CRV, 2016. 184 p.

LIMA, Nádia Gilma Beserra de. **Análise microclimática dos manguezais da Barra do Ribeira-Iguape/SP**. 2009. Dissertação (Mestrado em Geografia Física) - Faculdade de Filosofia, Letras e Ciências Humanas, University of São Paulo, São Paulo, 2009. doi:10.11606/D.8.2009.tde-07122009-100104. Acesso em: 2024-08-14.

LIMA, Nádia Gilma Beserra de. **Interação dos atributos climáticos nos manguezais do litoral sul de São Paulo e sua relação com os controles climáticos**. 2014. Tese (Doutorado em Geografia Física) - Faculdade de Filosofia, Letras e Ciências Humanas, University of São Paulo, São Paulo,2014. doi:10.11606/T.8.2014.tde-08052015-125807. Acesso em: 2023-08-22.

LIMA, Nádia Gilma Beserra de., Galvani Emerson. Interação dos atributos climáticos nos manguezais do litoral sul de São Paulo e sua relação com os controles climáticos. **Confins** [Online], 36 | 2018, posto online no dia 28 julho 2018, consultado o 30 julho 2024. URL: http://journals.openedition.org/confins/14724; DOI: https://doi.org/10.4000/confins.14724

LIMA, Beserra & de Lima, Nadia Gilma & Galvani, Emerson. (2013). Mangrove Microclimate: A Case Study from Southeastern Brazil. **Earth Interactions.** 17. 1-16. 10.1175/2012EI000464.1.

LIMA, N. G. B. DE .; CUNHA-LIGNON, M.; GALVANI, E.. Microclimatic analysis of mangroves in two distinct categories of Protected Areas and conserved status. **Sociedade & Natureza,** v. 33, p. e57483, 2021.

MONTEIRO, C. A. F. **A frente polar atlântica e as chuvas de inverno na fachada sul-oriental do Brasil: Contribuição metodológica à análise rítmica dos tipos de tempo no Brasil.** São Paulo: Instituto de Geografia, Universidade de São Paulo, 1969. 68 p.

MONTEIRO, C. A. F **A dinâmica climática e as chuvas no Estado de São Paulo: estudo geográfico sob forma de Atlas.** São Paulo: Instituto de Geografia, Universidade de São Paulo, 1973. 130 p.

NOVAIS, G. T. (Org). **Climas do Brasil: classificação climática e aplicações.** Porto Alegre : Totalbooks, 2023.

NOVAIS, G. T. **Classificação climática aplicada ao Bioma Cerrado**. 2019. Tese. (Doutorado em Geografia) - Instituto de Geografia da Universidade Federal de Uberlândia. 2019.

RIBEIRO, Antonio Giacomini. As escalas do clima**. Boletim de Geografia Teorética,** v. 23, n. 45-46, p. 288-294, 1993.

SCHAEFFER-NOVELLI, Y, et al. Manguezal: ecossistema entre a terra e o mar**.** São Paulo: **Caribbean Ecological Research**, 1995.

TARIFA, J. R. **Unidades climáticas dos maciços litorâneos da Juréia-Itatins. In: Estação Ecológica Juréia-Itatins: Ambiente Físico, Flora e Fauna.** Org. Otavio A.V. Marques; Wânia Duleba. São Paulo: Holos. 2004. p. 42 a 50.

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Author 1: Preparation, text production and discussion of results
Author 2: Supervision, discussion of results, bibliographic research, text review
Author 3: Preparation, text production and discussion of results