CYCLONE TRACK ANALYSIS BASED ON 10 YEARS OF SYNOPTIC CHARTS FOR THE SOUTHWESTERN ATLANTIC (METAREA V)

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Abstract

Extratropical cyclones are weather phenomena with significant transfer of energy between the surface (over the ocean or on land) and the atmosphere. Recurrently, reanalysis data are used to understand the behavior of cyclonic tracks and to study extreme events, with constant updates and validations with the observational base in the Northern Hemisphere. However, studies using cyclone tracking in the Southwestern Atlantic, has proven more difficult. This disagreement seems to be in function of the structure and intensity of the forcing factors that influence both cyclogenesis and the displacement to the South Atlantic, when compared to the Northern Hemisphere. In this work, synoptic pressure charts at sea level, manually made and processed by the Brazilian Navy every 12 hours between the years 2010 and 2020, as a product resulting from a consensus among Navy meteorologists, were used to study the cyclonic pathways in the Southwestern Atlantic (METAREA V). Data obtained for all cyclones identified in the charts, based on their position and displacement, formed a database with 10737 cyclones, containing speed, dimensions, and pressure gradient. The cyclones identified have a higher radius frequency between 200/400 km and a faster-moving center shift. In addition, about 60% of cyclones associated with cold fronts have a life cycle ranging from 3 to 4 days. There is also a expressive cyclogenesis between latitudes 23ºS and 43ºS where, in austral autumn winter, increases its frequency over the ocean and close to the southern Brazilian coast. During spring, the greater cyclogenesis frequency occurs over the continent, close to Chaco area in Argentina and Uruguay. The impacts of these statistical figures on the south and southeastern Brazilian coast, mainly the continental insertion point of the cold fronts and cyclonic displacement that influence rough seas and storm surges, are discussed in this work. Keywords: EXTRATROPICAL CYCLONES, CYCLONE TRACK, SYNOPTIC CHARTS, SOUTHWESTERN ATLANTIC

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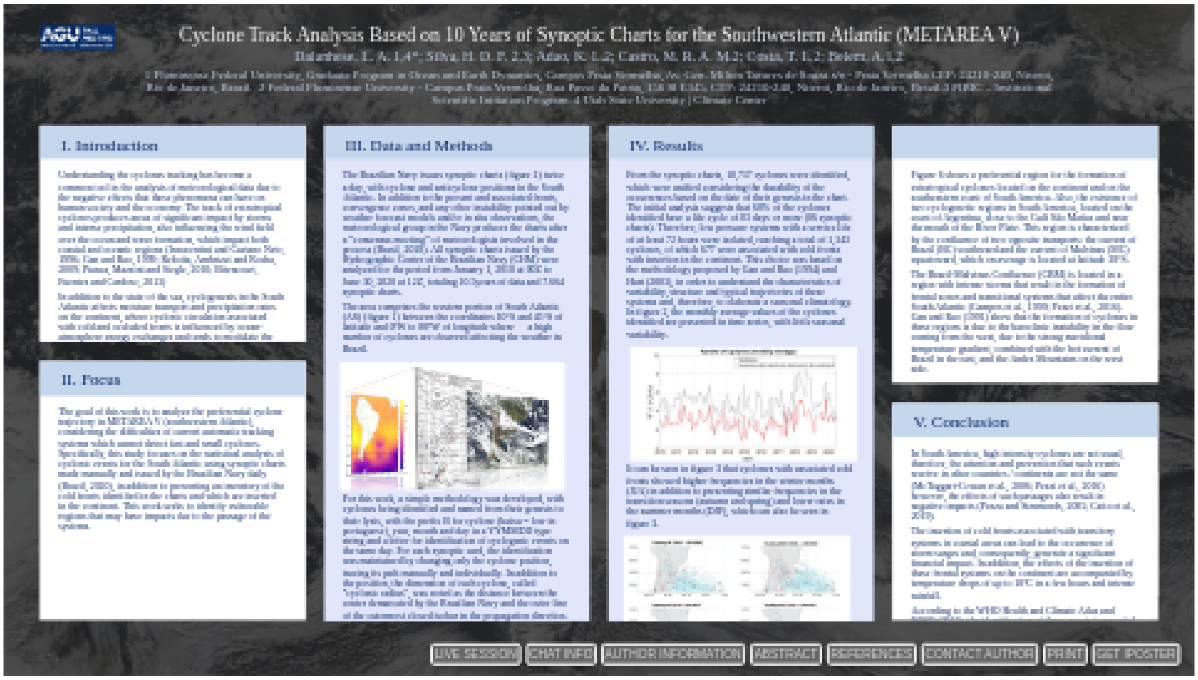

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I. INTRODUCTION

Understanding the cyclones tracking has become a common tool in the analysis of meteorological data due to the negative effects that these phenomena can have on human society and the economy. The track of extratropical cyclones produces areas of significant impact by storms and intense precipitation, also influencing the wind field over the ocean and wave formation, which impact both coastal and oceanic regions (Innocentini and Caetano Neto, 1996; Gan and Rao, 1999; Reboita, Ambrizzi and Rocha, 2009; Pianca, Mazzini and Siegle, 2010; Bitencourt, Fuentes and Cardoso, 2013)

In addition to the state of the sea, cyclogenesis in the South Atlantic affects moisture transport and precipitation rates on the continent, where cyclonic circulation associated with cold and occluded fronts is influenced by ocean-atmosphere energy exchanges and tends to modulate the climate regime in land. Intense rains are induced not only by cyclonic circulation, but also by a set of factors associated with it (Carvalho, Jones and Liebmann, 2002; Nielsen et al., 2016; Bernardino, Vasconcellos and Nunes, 2018). Fortune and Kousky (1983) and also Pezza and Ambrizzi (2000) report cyclonic behavior with rainfall and damage rates in Brazilian agrarian production.   .

Most of the cyclogenesis in South America occurs on the continent, between the northwest Argentina, northern of the Paraguay-Bolivian Chaco and eastern of the Andes, which due to its orographic influence the pattern of low-level jet is affected and, consequently, the vast area subject to low pressure zones with incidence of transient systems, most evident during the southern summer (Seluchi and Garreaud, 2012; Seluchi and Saulo, 2012; Falco et al., 2019).

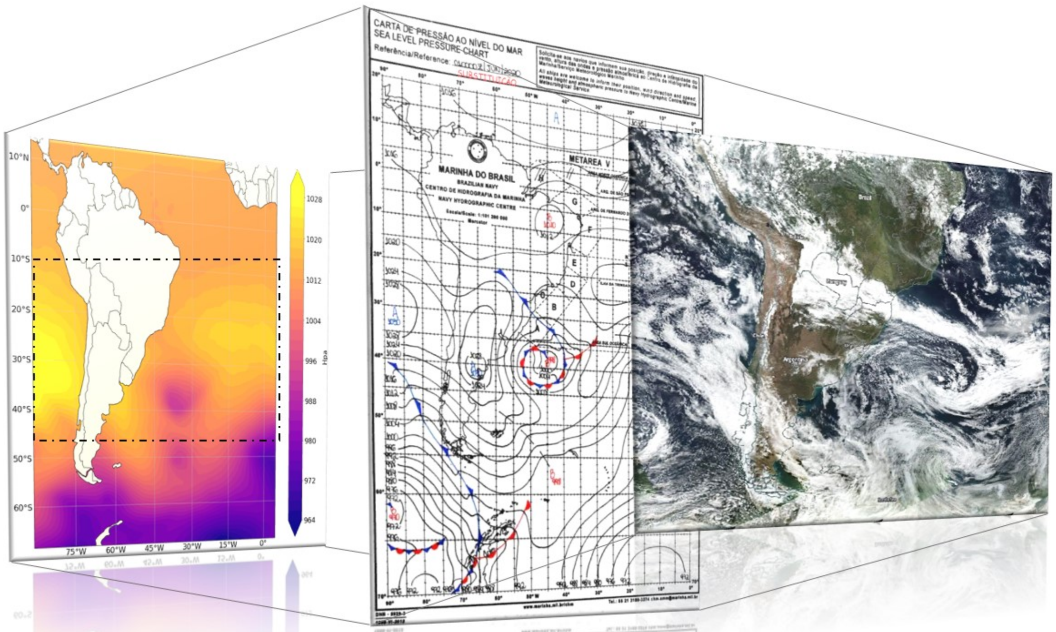
II. FOCUS

The goal of this work is to analyze the preferential cyclone trajectory in METAREA V (southwestern Atlantic), considering the difficulties of current automatic tracking systems which cannot detect fast and small cyclones. Specifically, this study focuses on the statistical analysis of cyclonic events for the South Atlantic using synoptic charts made manually and issued by the Brazilian Navy daily (Brazil, 2020), in addition to presenting an inventory of the cold fronts identified in the charts and which are inserted in the continent. This work seeks to identify vulnerable regions that may have impacts due to the passage of the systems.

III. DATA AND METHODS

The Brazilian Navy issues synoptic charts (figure 1) twice a day, with cyclone and anticyclone positions in the South Atlantic. In addition to the present and associated fronts, convergence zones, and any other instability pointed out by weather forecast models and/or in situ observations, the meteorological group in the Navy produces the charts after a “consensus meeting” of meteorologists involved in the process (Brasil, 2018). All synoptic charts issued by the Hydrographic Center of the Brazilian Navy (CHM) were analyzed for the period from January 1, 2010 at 00Z to June 30, 2020 at 12Z, totaling 10.5years of data and 7.664 synoptic charts.

The area comprises the western portion of South Atlantic (AS) (figure 1) between the coordinates 10°S and 45°S of latitude and 0ºW to 80ºW of longitude where a high number of cyclones are observed affecting the weather in Brazil.

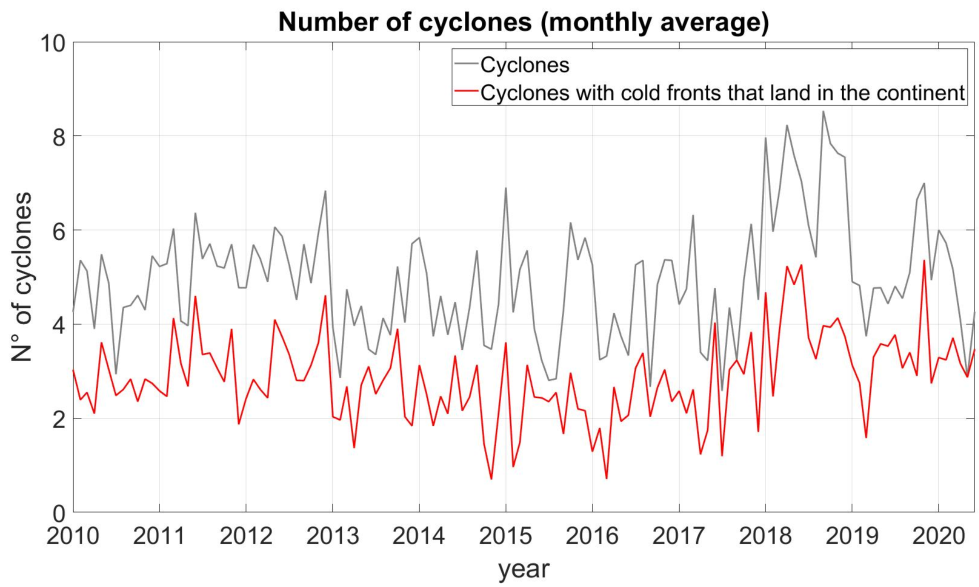


For this work, a simple methodology was developed, with cyclones being identified and named from their genesis to their lysis, with the prefix B for cyclone (baixa = low in portuguese), year, month and day in a YYMMDD type string and a letter for identification of cyclogenic events on the same day. For each synoptic card, the identification was maintained by changing only the cyclone position, tracing its path manually and individually. In addition to the position, the dimension of each cyclone, called "cyclonic radius", was noted as the distance between the center demarcated by the Brazilian Navy and the outer line of the outermost closed isobar in the propagation direction. The measurement on the chart was converted from lat/lon coordinates to kilometers.

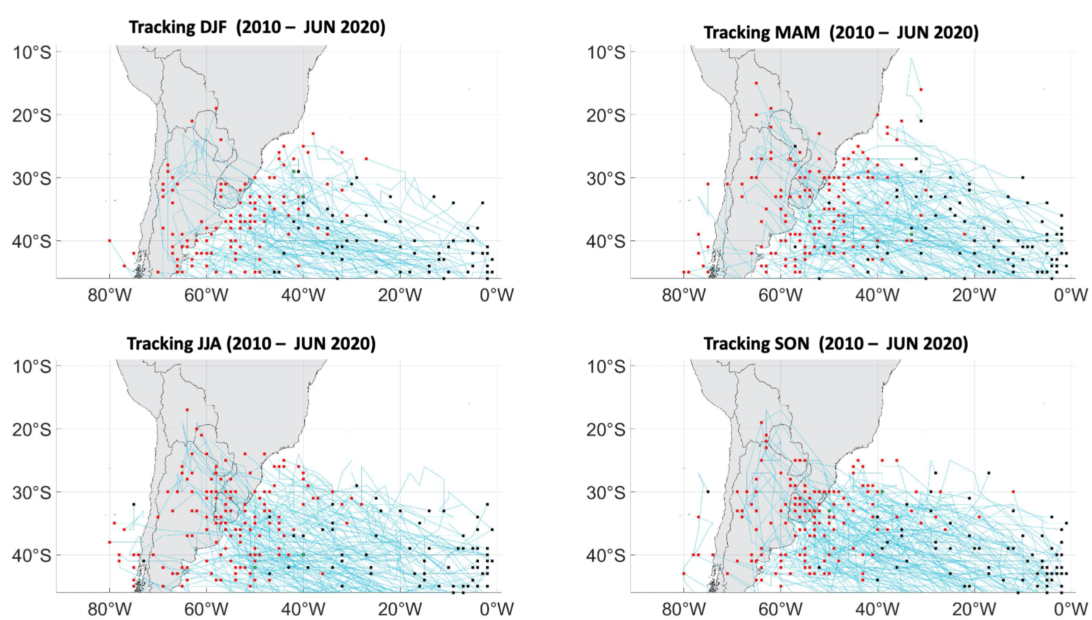
To assess the speed, the distance traveled by the cyclone was analyzed considering its initial latitude/longitude and its position on the next chart. This distance was calculated in degrees and later converted into kilometers, divided by 12 hours (the time between two consecutive synoptic charts of the Brazilian Navy). Quantitative statistical analyzes were carried out in order to evaluate the consistency of the data generated, the occurrence of cyclones over time, cold fronts associated with cyclones and other phenomena mentioned above. Monthly and annual averages were performed evaluating the occurrence of cyclones, frequency histograms and their respective association with the cyclonic radius, in addition to the displacement speeds of the cyclonic centers.

IV. RESULTS

From the synoptic charts, 10,737 cyclones were identified, which were unified considering the durability of the occurrences based on the date of their genesis in the chart. The initial analysis suggests that 60% of the cyclones identified have a life cycle of 03 days or more (06 synoptic charts). Therefore, low pressure systems with a service life of at least 72 hours were isolated, reaching a total of 1,343 cyclones, of which 677 were associated with cold fronts with insertion in the continent. This choice was based on the methodology proposed by Gan and Rao (1994) and Hart (2003), in order to understand the characteristics of variability, structure and typical trajectories of these systems and, therefore, to elaborate a seasonal climatology. In figure 2, the monthly average values of the cyclones identified are presented in time series, with little seasonal variability.

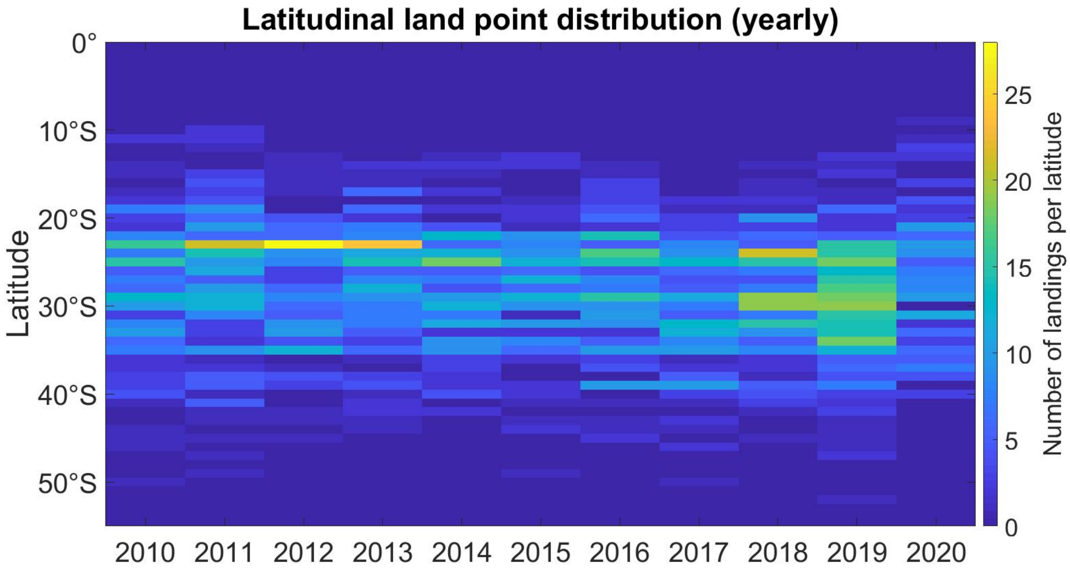


It can be seen in figure 3 that cyclones with associated cold fronts showed higher frequencies in the winter months (JJA) in addition to presenting similar frequencies in the transition seasons (autumn and spring) and lower rates in the summer months (DJF), which can also be seen in figure 3.



Another important factor is the latitude of occurrence of such landings (insertion) on the continent. Figure 4 shows the preferred landing latitude of the fronts, as well as the number of cold fronts associated with cyclones entering the continent.

In the case of demarcated landing points on the continent, it is clear that the occurrence of their insertion is well distributed over practically the entire east coast of the South American continent. However, the largest number of landings occurs in the south and southeast of Brazil, extending through Uruguay and Argentina (figure 5), where the harsh winter is more common than in other regions.


Latitudinal land point distribution (yearly)
Latitude
Number of landings per latitude
0°
10°S
20°S
30°S
40°S
50°S
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
0
5
10
15
20
25

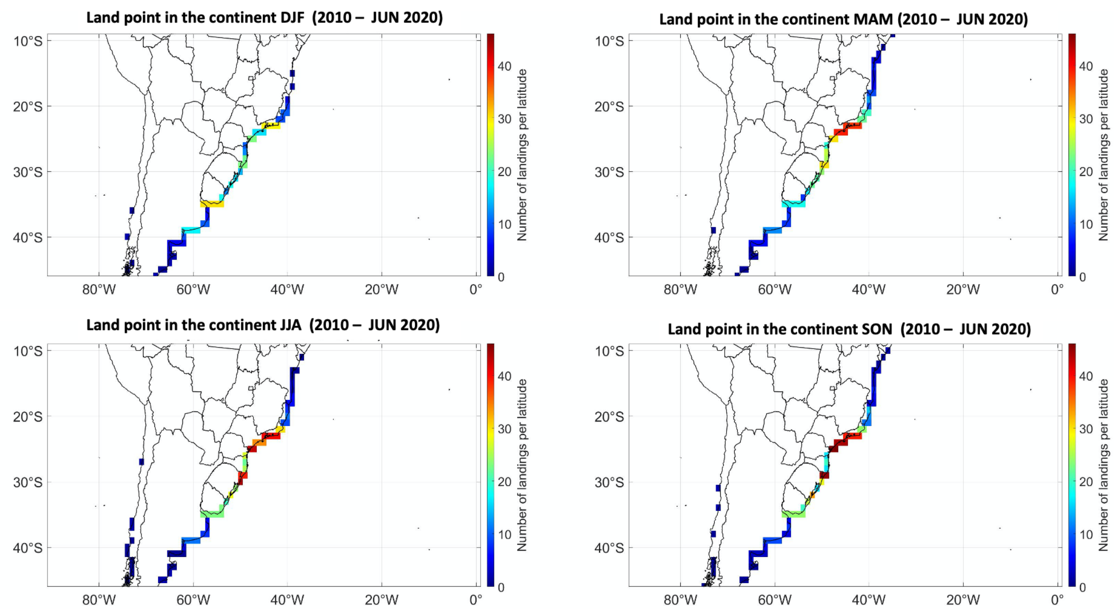
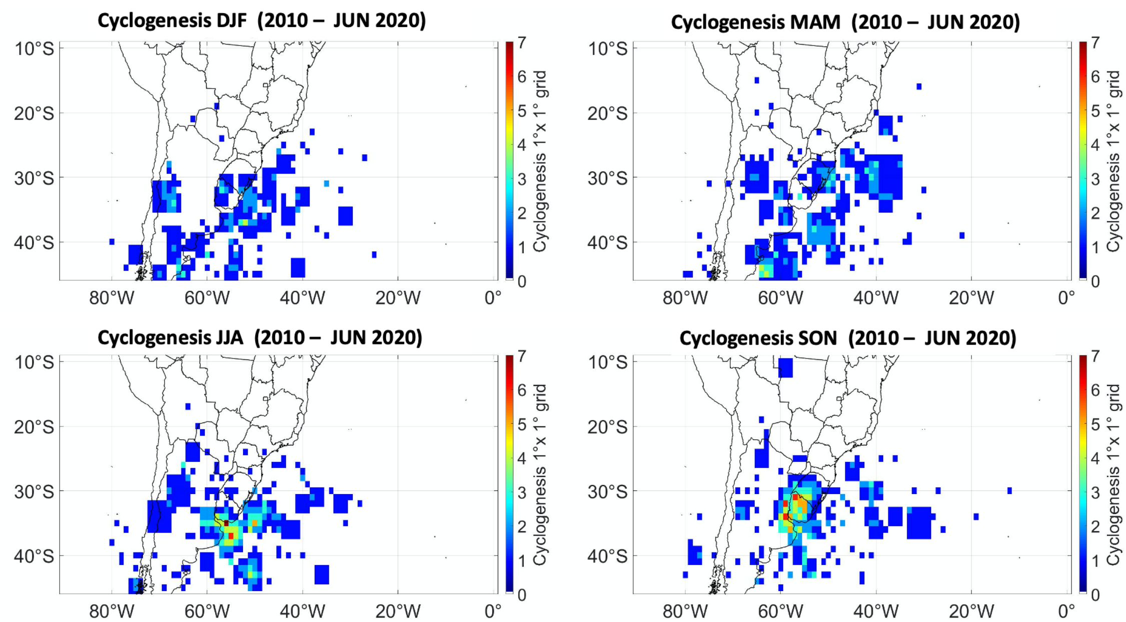

Land point in the continent DJF (2010 – JUN 2020)
Land point in the continent MAM (2010 – JUN 2020)
Land point in the continent JJA (2010 – JUN 2020)
Land point in the continent SON (2010 – JUN 2020)
Number of landings per latitude
10°S
20°S
30°S
40°S
80°W
60°W
40°W
20°W
0°
0
10
20
30
40

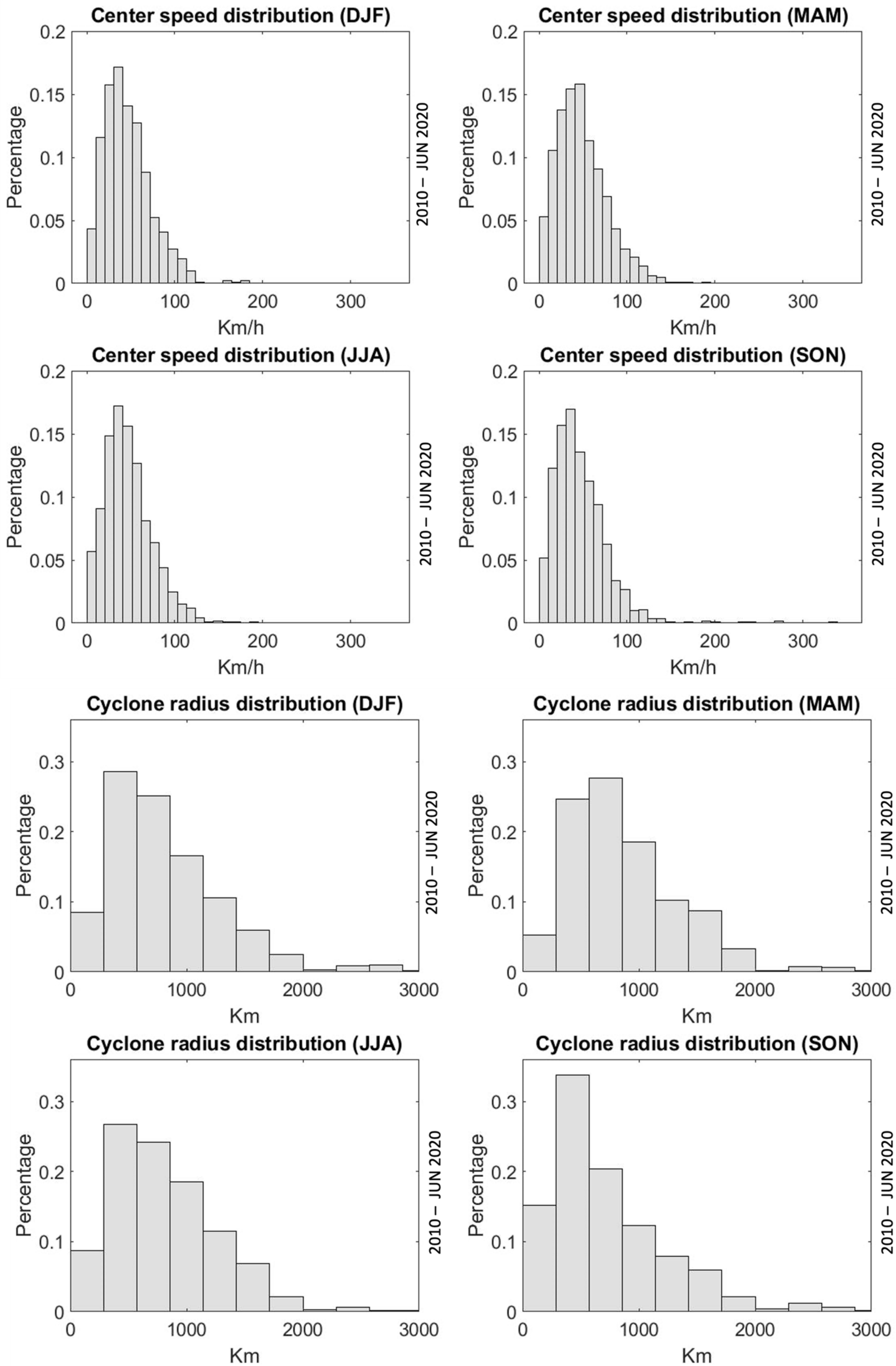
Figure 6 shows a preferential region for the formation of extratropical cyclones located on the continent and on the southeastern coast of South America. Also, the existence of two cyclogenetic regions in South America, located on the coast of Argentina, close to the Gulf São Matias and near the mouth of the River Plate. This region is characterized by the confluence of two opposite transports: the current of Brazil (BC) southward and the current of Malvinas (MC) equatoward, which on average is located at latitude 38°S.

The Brazil-Malvinas Confluence (CBM) is located in a region with intense storms that result in the formation of frontal zones and transitional systems that affect the entire South Atlantic (Campos et al., 1999; Pezzi et al., 2016). Gan and Rao (1991) show that the formation of cyclones in these regions is due to the baroclinic instability in the flow coming from the west, due to the strong meridional temperature gradient, combined with the hot current of Brazil in the east, and the Andes Mountains on the west side.



It is possible to observe that, in all seasons, the average displacement speed of extratropical cyclones is around 40 km / h, a value consistent with that found by Reboita et al. (2010).

Analyzing the average dimensions of the extratropical cyclones identified in this work, during all seasons the cyclonic rays vary in size from 100 to 3000 km (figure 8), being more frequent in the range of 300 to 2000 km.



V. CONCLUSION

In South America, high intensity cyclones are not usual, therefore, the attention and prevention that such events receive in other countries / continents are not the same (McTaggart-Cowan et al., 2006; Pezzi et al., 2016) however, the effects of such passages also result in negative impacts (Pezza and Simmonds, 2005; Catto et al., 2019).

The insertion of cold fronts associated with transitory systems in coastal areas can lead to the occurrence of storm surges and, consequently, generate a significant financial impact. In addition, the effects of the insertion of these frontal systems on the continent are accompanied by temperature drops of up to 10ºC in a few hours and intense rainfall.

According to the WHO Health and Climate Atlas and WMO (2012), the identification of these events is essential for the development of effective risk management strategies. Effective strategies are based on historical and real-time observations of events, as well as information on vulnerability, exposure (Resio and Irish, 2015) and past events, and possible future conditions. Irish and Resio (2010) state that in order to assess the impacts caused by a cyclone, a study of the history of events and their effects must be carried out.

This study surveys the statistical data of 10 and a half years of cyclonic occurrences identified by the Brazilian Navy, observing a greater incidence of cyclones associated with cold fronts in the winter period, being accompanied by a high frequency of these occurrences in transition stations.

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ABSTRACT

Extratropical cyclones are weather phenomena with significant transfer of energy between the surface (over the ocean or on land) and the atmosphere. Recurrently, reanalysis data are used to understand the behavior of cyclonic tracks and to study extreme events, with constant updates and validations with the observational base in the Northern Hemisphere. However, studies using cyclone tracking in the Southwestern Atlantic, has proven more difficult. This disagreement seems to be in function of the structure and intensity of the forcing factors that influence both cyclogenesis and the displacement to the South Atlantic, when compared to the Northern Hemisphere. In this work, synoptic pressure charts at sea level, manually made and processed by the Brazilian Navy every 12 hours between the years 2010 and 2020, as a product resulting from a consensus among Navy meteorologists, were used to study the cyclonic pathways in the Southwestern Atlantic (METAREA V). Data obtained for all cyclones identified in the charts, based on their position and displacement, formed a database with 10737 cyclones, containing speed, dimensions, and pressure gradient. The cyclones identified have a higher radius frequency between 200/400 km and a faster-moving center shift. In addition, about 60% of cyclones associated with cold fronts have a life cycle ranging from 3 to 4 days. There is also a expressive cyclogenesis between latitudes 23ºS and 43ºS where, in austral autumn winter, increases its frequency over the ocean and close to the southern Brazilian coast. During spring, the greater cyclogenesis frequency occurs over the continent, close to Chaco area in Argentina and Uruguay. The impacts of these statistical figures on the south and southeastern Brazilian coast, mainly the continental insertion point of the cold fronts and cyclonic displacement that influence rough seas and storm surges, are discussed in this work.

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