CLIMATOLOGY OF THE WINDS ALONG THE BRAZILIAN COAST

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Abstract. Wind is a very important meteorological variable in the physical processes of the atmosphere, playing a decisive role in the distribution of heat and humidity. Although the wind is a parameter of great importance for understanding convective effects, to obtain a good knowledge of the winds, the analysis of data in a short period is not enough, the ideal would be the analysis of data relating to several years. The use of information derived from remote platforms such as satellites or airborne sensors is increasing, especially for studies of the behavior of winds on the sea surface. From the wind speed data by the Blended Sea Winds (BSW) product of level 4 processing, made available by the Copernicus Marine Service, historical series of wind speeds were extracted every 6 hours, for the 4 main synoptic times, from 1992 to 2018. The study area comprises the entire coastline of the coast of Brazil from the northern border with French Guiana to the southern border with Uruguay and extends between the parallels 5° N and 36° S latitude, and 55° W and 20° W longitude. To study the variation of wind speed over time, 18 points were chosen and from them annual, seasonal and monthly wind speed graphs were made. Historical, seasonal and hourly average speed calculations were made, and maps were generated for each average, as well as speed variance calculations. The results show that the average offshore wind speeds off the Brazilian coast range from 4 m/s to 10 m/s, and its greatest variation is latitudinal. The seasons of the year have a great influence on the average wind speeds in Brazil and the spring season has the highest wind speeds.

Keywords. Wind, blended sea winds, Brazil, offshore, climatology here your keywords, separated from each other with a comma.

1. Introduction

Wind is a very important meteorological variable in the physical processes of atmosphere, plays a decisive role in the distribution of heat and humidity. Its variability has great importance in defining the weather and climate of a region and varies according to the location, topography and surface, and time of year [1] [2].

There are many studies that apply the wind potential analysis to applications in wind energy in Brazil, but there are few works relating trends in wind speed with climatological changes, or with atmospheric circulation for the entire coast of Brazil [3][4]. Some, carry out analyzes only for the Northeast Brazilian. [5].

According to Lopes and De Moura [6]. Despite the winds exert beneficial functions for human life, when winds with are registered, their effects become harmful and cause soil erosion, death of animals, the lodging of plants, the roofing of buildings and the falling of nets transmission, in the offshore environment there may be an increase in wave amplitude, coastal erosion.

According to the report of the Intergovernmental Panel on Climate Change (IPCC), changes in extreme events (both in frequency and intensity) of weather and climate have been observed since 1950. year, several parts of the globe face regional climatic anomalies, such as droughts, record colds and an unusual number of storms, as well as extremes related to climate change such as heat waves, floods and cyclones [7].

Some authors have also studied the behavior of wind in relation to time. It is reported that the amount of energy available in the wind, and hence its speed, varies according to the seasons of the year and the

time of day[6] [2].

The wind time series have random and non-stationary, so they are complex to analyze and carry out studies on short-range or long-range predictions or correlations. In this way, a probabilistic prediction and statistical analysis of wind behavior are very important for identifying of patterns, identification of influencing systems, and soon, applications in engineering and energy, and mainly in climate studies [8].

The objectives of this work are:

- Determine average wind speed patterns for the entire coast of Brazil for the historical period of 27 years,

- Determine the effects of seasonality on winds.

- Statistical analysis of the trend of the average wind speed.

2. Area of study

The area of study (Figure 1) comprises the entire coast of Brazil from the border north with French Guiana to the southern border with Uruguay and extends between the parallels 5º N and 36º S of latitude, and 55º W and 20º W of longitude.

For observations of temporal variation, 18 points were chosen around the the entire coast of the country, each pair of points shared the same latitude, and were spaced with 5° in longitude to each other.

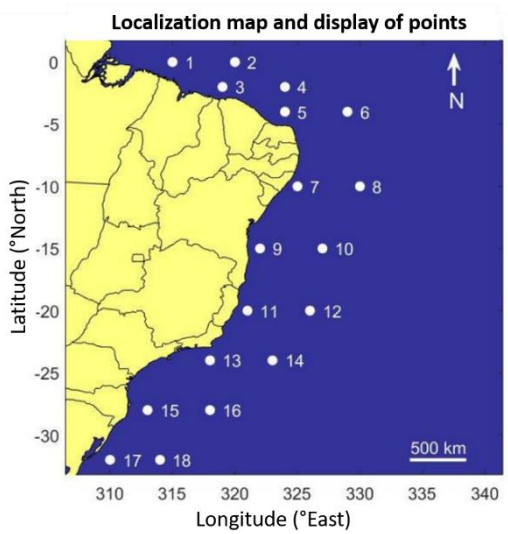

Fig 1 - Map of the area of study and the display of sampling points

3. Methodology

3.1 Blended Sea Winds

Blended Sea Winds (BSW) data was made available by Copernicus Marine Service, the marine component of the European Earth Observation Program COPERNICUS in NetCDF-4 (Network Common Data Form) format.

The BSW product is level 4 of processing and is composed of the components (meridional and zonal) of the wind speed and voltage. The products are measured by scatterometers (ASCAT-A, ASCAT-B, SCATSAT, HY-2B) and radiometers (SSM/I and SSMIS) with spatial resolution of 0.25° in longitude and latitude over the ocean for a fixed height of 10 meters above the sea level.

The extracted historical series comprises speed averages dated every 6 hours in the period from January 1, 1992 to December 31, 2018. Analyzes are carried out to the main synoptic times for Coordinated Universal Time (UTC-Universal Coordinated Time), being them 00:00:00, 06:00:00, 12:00:00 and 18:00:00, totaling 39,444 observations.

3.2 Data for the analysis

Data processing and analysis were performed in Matlab® software version R2019a, and were divided into the following parts: assembly of the velocity matrix, calculation of the means, and statistical analysis of the tendencies.

From the BSW dowloaded data, a 4D matrix was generated with the following dimensions: Latitude x Longitude x Wind Speed x Time, containing all speeds for the 4 analyzes rates for the entire 27-year period.

3.3 Calculation of seasonal averages

For better statistical application, the matrix averages were calculated for 2 different resolutions, the first being the climatological average for the entire period and the second as the seasonal historical average for each of the seasons, separated into: Summer (December, January and February), Autumn (March, April and May), Spring (June, July and August) and Winter (September, October and November). Thus, maps were generated for each average.

4. Results

4.1 Historical Average Speed

The average wind speed map (Figure 2) calculated from all historical averages that comprise the 27 years of acquisition have speeds that vary from 2 m/s to 8 m/s. There is a certain pattern for latitudinal bands, a wider range of speeds to the north followed by a lane with higher speeds, this is repeated to the south of Brazil.

The distribution of wind speeds around the coast of Brazil in the first 100 km and up to 400 km in the concave part of the coast between the southeast and south regions have the values wind speeds, much of it below 5.5 m/s and some points in the region southeast and north below 4 m/s. The northern region of Brazil has the highest historical averages for the speed of the wind, mainly between the states of Maranhão and Pernambuco. The highest averages concentrated in the north of Piauí, Ceará and Rio Grande do Norte, where there is an area with high speeds very close to shore. This area is followed by a

large extension of high speeds above the ocean, between latitudes 5°S and 15°S. This area of more intense winds corresponds to the behavior of the trade winds, components of the general circulation atmosphere, received by the northeast region of the country [9].

Below this high speed range we have a reduction in the average values, the coast of the state of Bahia and Espírito Santo receive the winds with the lowest speeds throughout the historical period. This low-speed area extends to southeast to cover latitudes between 15°S and 30°S. Dereczynski et al [10] state that the Southeast region of Brazil and the ocean is directly influenced by the subtropical high of the Atlantic South throughout the year. Such a system is responsible for the northeasterly winds of low intensity that predominate in the region. As well as the North region, the states of Santa Catarina and Rio Grande do Sul receive high-speed winds, a speed zone of at least 7.5 m/s. medium to high speed area extends from the coast of rio de janeiro to southern country, and on the high seas follows the behavior of the other two areas. This wind zone with higher speeds occurs due to the westerly winds that predominate over the local circulation.

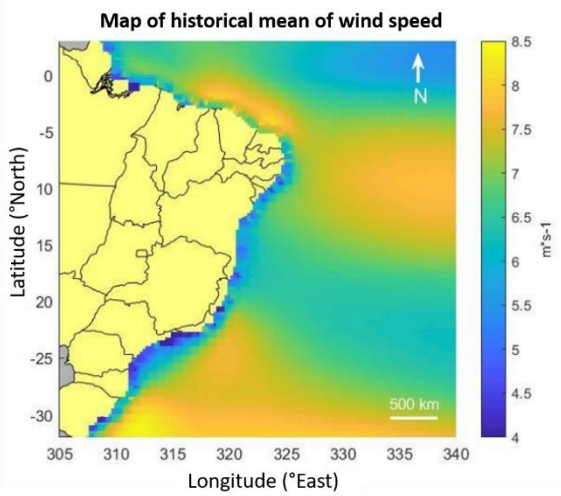

Fig 2 - Map of average of historical wind speed.

4.2 Seasonals averages

The same pattern presented in the historical climatological average is repeated when the averages are separated by seasons (Figure 3), but in different intensities.

The average speed map for winter has the same speeds along longitudinal bands, however, beyond the shoreline areas, there is no speeds lower than 6 m/s, being the station with the highest wind speeds for the entire coast of the country. The coast of the northeast region receives winds that reach up to of 9 m/s.

The feature that draws attention is the shape and behavior of the trade wind range of high speed that is located in the northeast region and extends to the east and south. the winds trades are shown on maps, more intense in spring and winter.

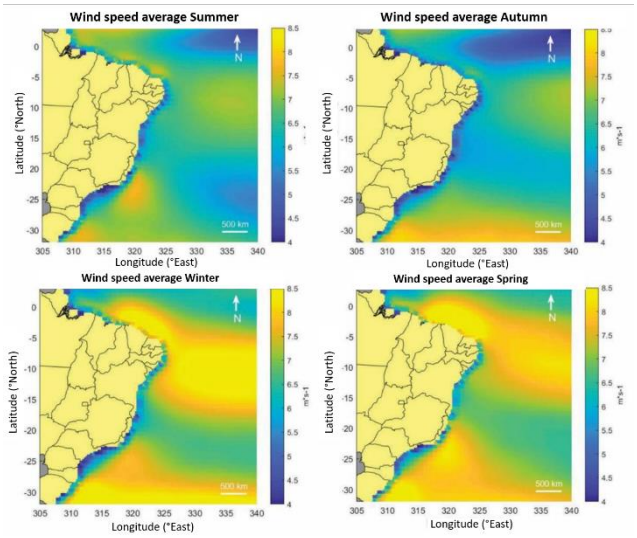

Fig 3 - Maps of wind speed average for each season of the year, Summer, Autumn, Winter, Spring.

In winter, the entire area has the same intensity of winds, which does not occur in the next season, spring. In spring, speeds are higher in the northern part of the than in the eastern part of the Northeast region, giving the impression that wind speeds are moving further and further north. This observation can be validated in the two following seasons, in the summer there is a weakening and there are remnants of this area of high speed more and more to the north, as well as winds with higher speed appear above 0° latitude, and an emergence of low-speed winds from higher longitudes.

Following the pattern of high-speed winds in the Northeast of the country, the the height winds of the southeast regions also follow the pattern reaching lower latitudes in the spring, and staying south in summer and autumn. Figure 4 shows the variations of the winds at points 3, 9 and 15 in temporal chart format for each station.

The shape and occurrence of stronger winds in the winter and spring seasons and, consecutively, the change in this band corresponds to the behavior of the intertropical convergence. Camelo et al [11] mentions that in the second half of the year the 27 of Intertropical Convergence (ITCZ) migrates to its northernmost position of its normal climatological condition, making the trade winds more intense in the region Northeast [12]. The absence of the high wind speed zone in the Northeast in the summer and autumn seasons can be explained with the displacement of the to above the equator [13].

As well as the area of low wind speeds that arises at 0° latitude and comes from high to low longitudes, is similar to the behavior of the convergence zone in the first half of the year, when it is lowest.

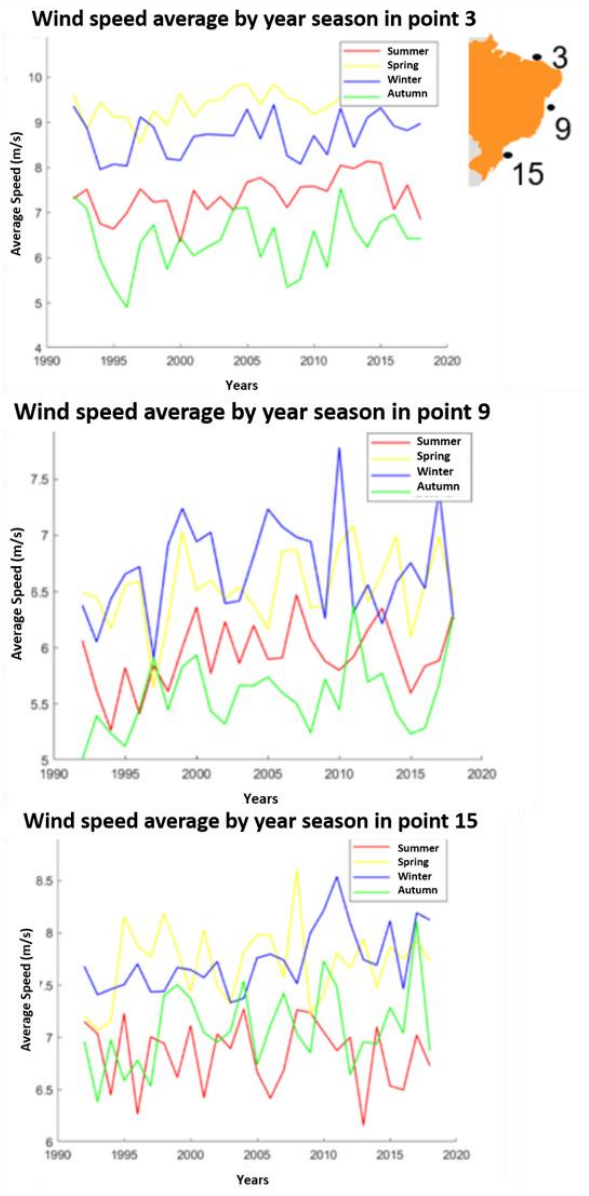

Fig 4 - Wind speed average by season on points 3, 9 and 15, each collor represents one season of the year.

4.3 Average speed trend analysis

The monthly average speed graphs (Figure 5) show a high frequency wavelength equivalent to about 12 months, which represents a fluctuation each year. From the linear regression performed on each speed function for each of the points, Table 1 was generated, which contains the angular and linear coefficients of the occupation.

The linear coefficients representing the cutoff of the function on the Y axis of velocity correspond to the wind intensities for each latitude where the points meet, the coefficients are higher in the areas with the highest velocities on the mean map climatology of the entire period.

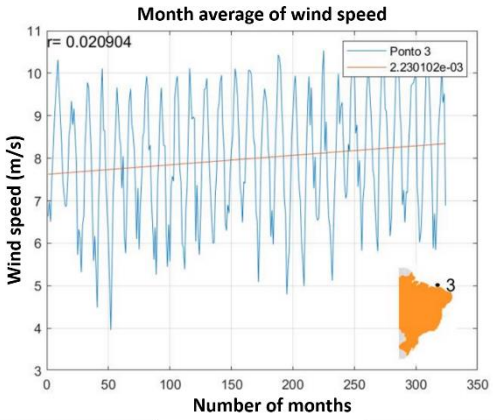

Fig 5 - Month average of wind speed, trend of the wind speed mean to point 3.

The slope represents the behavioral trends of the velocity wind average. According to Table 1, the analysis of climate trends in maximum wind speed shows positive trends, represented by the blue color. You slopes are raised to the third or fourth power, which indicates a smooth trend.

The generated table shows positive trends throughout the Brazilian coast. of this way, it is possible to affirm that there is an increase in the average speed of the winds throughout the coastal extension of Brazil.

The points closest to the coast, represented by the darkest blue color, have greater slope of the line than the points spaced by 5° of Latitude, represented by the light blue color, which are further from the coast.

Tab. 1 – Coefficients of linear regression of wind speed average.

Point	angular coefficient	linear coefficient
1	8,27E-04	6,79
2	7,08E-04	7,01
3	2,23E-03	7,62
4	5,61E-04	7,03
5	1,85E-03	7,62
6	2,23E-04	6,93
7	1,41E-03	6,5
8	6,14E-04	7,43
9	1,17E-03	5,99
10	6,09E-04	6,77
11	7,70E-04	6,57
12	2038E-04	6,44
13	1,12E-03	6,92
14	3,35E-04	7,15
15	1,08E-03	7,17

16	3,78E-04	7,46
17	1,03E-03	7,91
18	5,85E-04	8,12

5. Conclusion

The climatological average over 27 years of wind speed data offshore Brazilian coast ranges from 4 m/s to 10 m/s, and its greatest variation is latitudinal, with that the highest speeds (between 7 and 10 m/s) are located on the coast of Northeast Brazil especially on the coast of the states of Ceará and Rio Grande do Norte, and occur due to

presence of the trade winds received in the region. As latitude increases, we have an area of low speeds (between 5 and 7 m/s) that extends along the coast of southern Bahia and the region southeast of the country, which is justified by the subtropical high of the South Atlantic that weakens the regional trade winds. In the South region, speeds increase again, but reaching values lower than in the Northeast region, due to the westerly winds.

The seasons of the year have a great influence on the average wind speeds. in Brazil. The spring season has the highest wind speeds, followed by winter, summer and autumn. The areas with the highest speeds on the coast of Northeast Brazil may be influenced by the displacement of the Intertropical Convergence Zone.

The average wind speed shows positive trends along the entire coast Brazilian. In this way, it is possible to affirm that there is an increase in the average speed of the winds along the entire coastline of Brazil.

Another form of trend analysis, that fit more the behave of average fluctuation, should be tested to be more accurate than linear regression.

6. References

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