Regions of the southern Atlantic ocean: A study on the sea surface temperature and sea surface salinity of the southern Atlantic Ocean region

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Abstract. Followed by the fast advancement of computer science and technology, studies involving massive datasets, especially environmental sciences, have been more accessible for researchers. Yet, with the completion of high-resolution data about the southern Atlantic Ocean region, there has not been sufficient academic research focusing on this specific area. In this regard, this paper investigates the connection between the Sea Surface Temperature (SST) and Sea Surface Salinity (SSS). The researchers chose South Atlantic as the research subject, and based on the visualization of the datasets from year 2010 to year 2014 to determine the number of clusters, the team applied k-means clustering to analyze the relation between SSS and SST by MATLAB. As a result, the research team found that the variation of the value of SSS and SST within the five years showed a stable tendency. The team classified the South Atlantic Ocean into four different oceanographical regions (based on the clusters acquired from the k-means technique), which each area showed a distinct feature in SSS and SST.

Keywords: k-means clustering, clusters, SSS, SST, South Atlantic Ocean.

1. Introduction

People in the contemporary world and the current generation have witnessed that people are paying more and more attention to the issue of the environment. The ocean, as an area that occupies most of the Earth's surface, plays an important role in the interference of balancing the environment. To protect the environment, people must first know how to protect the ocean. Ocean has different functions in different areas. To figure out methods of protecting the ocean, people should conduct a comprehensive research and analysis of the ocean. SST and SSS are two key factors in analyzing the ocean. They can affect the density and flow of seawater, thereby affecting the marine environment and ecosystems near or in the ocean: The higher the temperature, the lower the density. The higher the salinity, the higher the density. Additionally, the moving and mixing of seawater can make the salinity distribution relatively uniform. Different factors are involved in the relationship between salinity and temperature. In addition, the changes in temperature in different sea areas are also helpful for exploring the issue of global warming. It can be seen that the temperature and salinity of the ocean have an important status in the analysis of the ocean and later research on the global environment. However, how to intuitively analyze the temperature and salinity of the ocean has become a problem. With the development of technology, people have many ways to measure and detect the two factors in the ocean, thus obtaining a lot of measurement data. But having these data alone is useless. People need to integrate and analyze them through other means. As the most intelligent and fastest algorithm in the world today, programming language is the best way to analyze these data. In response to this issue, the research team prepared to study the salinity and temperature in the South Atlantic Ocean. MATLAB, as one of the common tools in coding, became our important tool. This research paper will comprehensively describe the process of this research. It will explain how the researchers use MATLAB to classify the salinity and temperature of different regions in the South Atlantic and present these abstract data clearly in charts and images [1].

2. Literature review: theoretical framework on clustering analysis and previous studies on Sea Surface Temperature and Sea Surface Salinity

Many studies have shown that data analysis, especially clustering analysis, is becoming a favorable tool for researchers in assessing oceanographical datasets. Jin found that the water masses of the South China Sea could be divided into different layers with distinct characteristics in SSS and SST using the k-means clustering analysis. Through this method, the research team proposed a seasonal variation model of how the South China Sea interacts with other surrounding water regions [2]. Similarly, Latto deploys clustering analysis to define ocean carbon cycles and patterns and examines how such a research method could assist environmental science fellows in heavy data-loaded research [3].

It is widely known that both SST and SSS determine many essential elements (for example, seawater density) in climate science, oceanography, and other environmental studies. Knowing their importance, previous studies have been done to inspect the SST and SSS and their influence in specific regions. Durack looked into the long-term SSS changes and proposed their conjectures for their importance to the global water cycle. Similarly, by examining the global SSS level over the range from 60°S to 60°N [4], Bingham suggests that instead of having a strong spacial trend, a seasonal pattern is more prevalent in the distribution of SSS in terms of global scale, which signifies the oceans' ability in regulating SSS variability [5]. Furthermore, Yu analyzed the sea surface temperature in the South China Sea and put forth a correlation between the wind trend and the SST trend front [6]. In addition, Yu revealed a significant correlation between the SST trend anomaly and the El Niño, suggesting the SST and its impact on the surrounding region [6].

Apart from the aforementioned research, other researchers investigated how SST and SSS are interrelated. The correlation coefficients of SST, SSS, and other elements in the field of environmental studies are closely examined by researchers. Hidayat had looked into the relationship between Chlorophyll-a, SSS, and SST. Focusing the research on the area near the Bay of Bengal, which often suffers from seasonal monsoon, the study concludes that Chlorophyll-a positively correlates with SST and maintains a negative relation with SSS [7]. Krivoguz examined the data collected in the region of the black sea and concluded that various elements, such as solar radiation and freshwater influx, would impact the level of SST and SSS in a region. More specifically, the SST and SSS are in an inverse relationship due to the influences from other environmental components [8]. Kido found that from a global scale, the variability between SST and SSS possesses a notable spatial scale dependence: most of the positive SST-SSS correlation coefficients are situated in the extratropic region and eastern tropical Pacific, suggesting that the particularity of such relationship [9].

Although past studies have investigated SST and SSS, whether in regional studies or from a global perspective, there has been little research focusing on the Southern Atlantic region, where detailed datasets have been collected but have never been utilized [1]. Using the method of clustering analysis, this study seeks to address the question: what is the relationship between the SSS and SST in the Southern Atlantic region, and what are its implications?

3. Methodology

This research is based on the method of machine learning: clustering analysis. Firstly, the research team utilized the data of SST, SSS, and the corresponding longitude latitude every month in the past 55 years

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to make the contour plots about the global value of SST and SSS, as shown in Figure 1. Based on the two plots, the researchers chose the South Atlantic to be the research subject (latitude: 65°S to 0°, longitude: 60°W to 30°W, the area is marked within the black box in Figure 1) because the values of SST and SSS change quickly in this area. To facilitate the research and avoid the burden of massive calculation, the team analyzed the data within the last five years in the datasets (2010-2014).

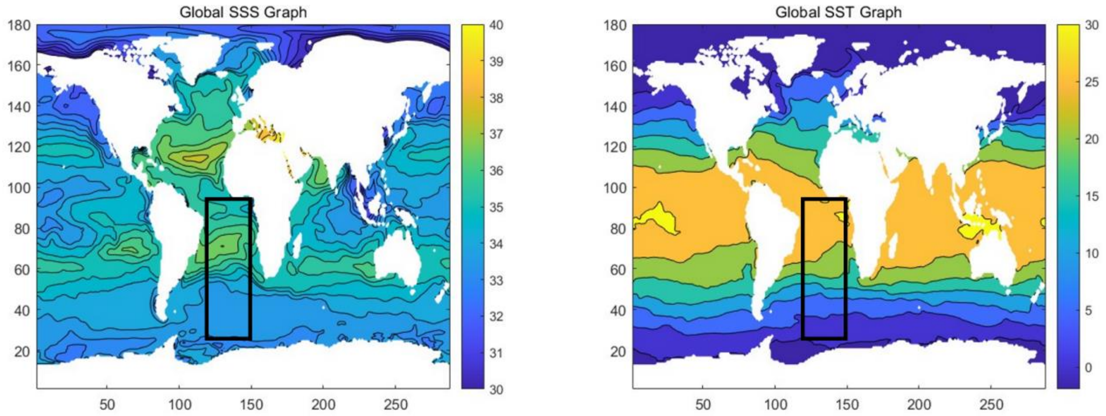

Figure 1. The position of the research subject in the graph of global SSS and SST.

Secondly, the datasets were processed. The researchers applied two different methods to accomplish this step:

Method 1: the team directly reshaped the form of the data of SSS and SST to reduce the dimensions and transform the 4-dimensional datasets into 2-dimensional matrix forms. Then, the team utilized k-means clustering to divide the datasets into several clusters and plotted the images of every cluster.

Method 2: the data of SSS and SST were divided into several intervals and reshaped into a matrix after counting how many sea areas fit each region. This enabled the researchers to turn the data into a histogram density graph (see Figure 2). And k-means clustering was applied to the density graph.

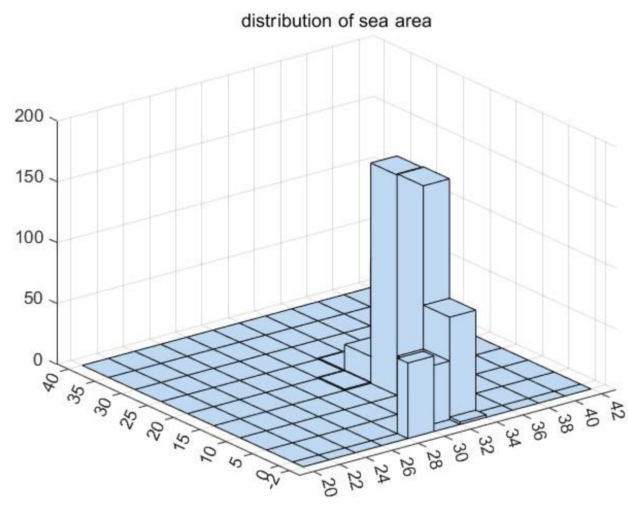

Figure 2. The distribution of sea area in different SSS and SST.

Note that, to determine the number of the clusters, the team started with an initial guess (denoted as k), and then change the numbers of the clusters based on the performance of the results: Firstly, the researchers were required to observe the images of every cluster. Then, if two or more images are similar, the number of clusters were to be reduced in to $k-1$; if no images are similar, the number of clusters were to be increased to $k+1$ to make a further guess of a finer result. Finally, the steps were repeated until a suitable number of clusters was found.

Compared with Method 1, the images Method 2 produced reflected the centroids of clusters. By contrasting the location of centroids, researchers were able to adjust the algorithm appropriately. On the contrary, Method 1 only reported the clusters. Thus, the researchers did not know the optimum number of clusters and could only modify the code with trial and error. Lastly, through analyzing these plots, the team produced results pertaining to variation of SST and SSS during a period of time and some features of South Atlantic seawater.

4. Result

In this study, analysis of those SSS and SST data showed that the southern Atlantic Ocean tends to have a spatial regionality based on their unique SSS and SST features, and the regions within the southern Atlantic Ocean underwent no significant changes from year 2010 to year 2014. The detail is elaborated as follows.

4.1. The variation of SSS and SST within five years

The researchers chose datasets of 5 years (from 2010 to 2014) to analyze the variation of SSS and SST.

Utilizing method 2 to process data, the researchers divided SSS and SST into narrow intervals to make it easier to detect the effect of clustering. The plots are as follows (year 2010).

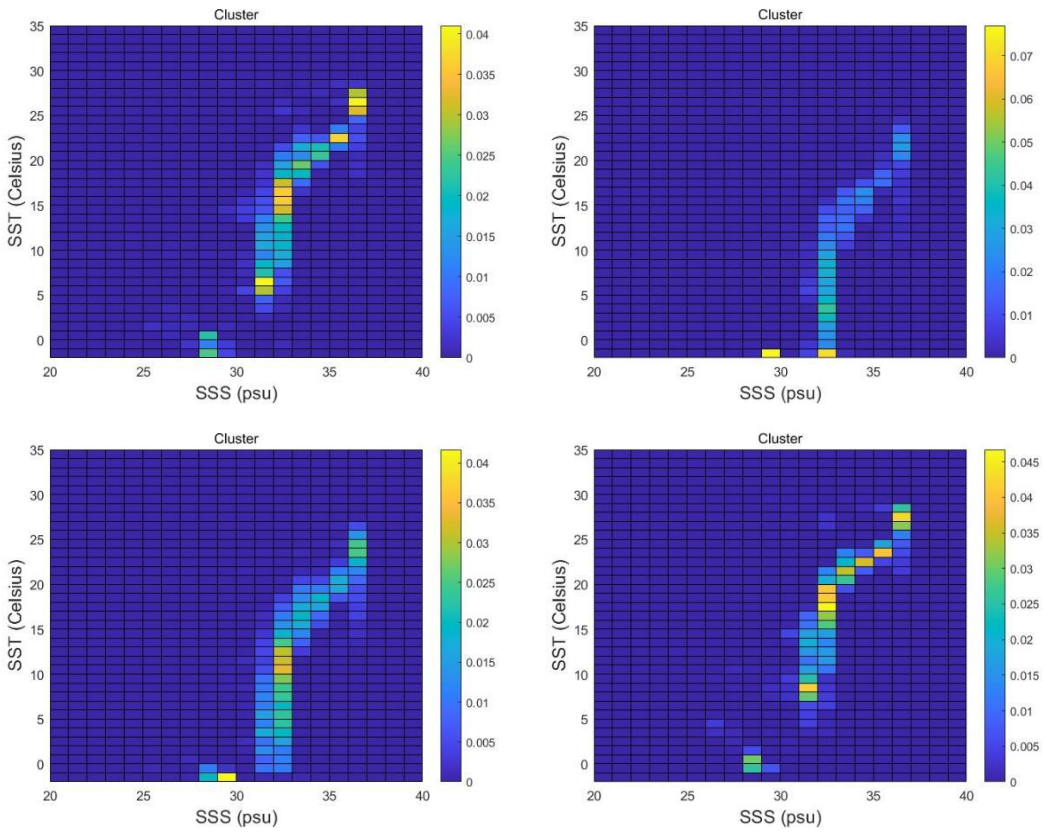

Figure 3. The distribution of sea area under different numbers of clusters.

The research team chose the grids with the highest ocean area values (the yellow grids in Figure 3). It calculated their average temperature and salinity (the middle point of every grid represents its temperature and salinity). Through the calculation of every cluster of every year, the data reads as follows.

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Table 1. The mean value of SSS and SST in different clusters within 5 years.

year	Cluster 1	Cluster 2	Cluster 3	Cluster 4
2011	(31, -1.5)	(31.75, 8.25)	(33.625, 19.875)	(33.8, 17.5)
2012	(29.5, -1.5)	(31, -1.5)	(33, 12.67)	(33.375, 18.75)
2013	(31, -1.5)	(31.75, 8.25)	(33.625, 19.875)	(34.055, 17.5)
2014	(30.75, -1.5)	(31, 4.5)	(33.64, 19.64)	(34, 19)
2015	(31, -1.5)	(31, 4)	(33.64, 22.8)	(34, 18.8)

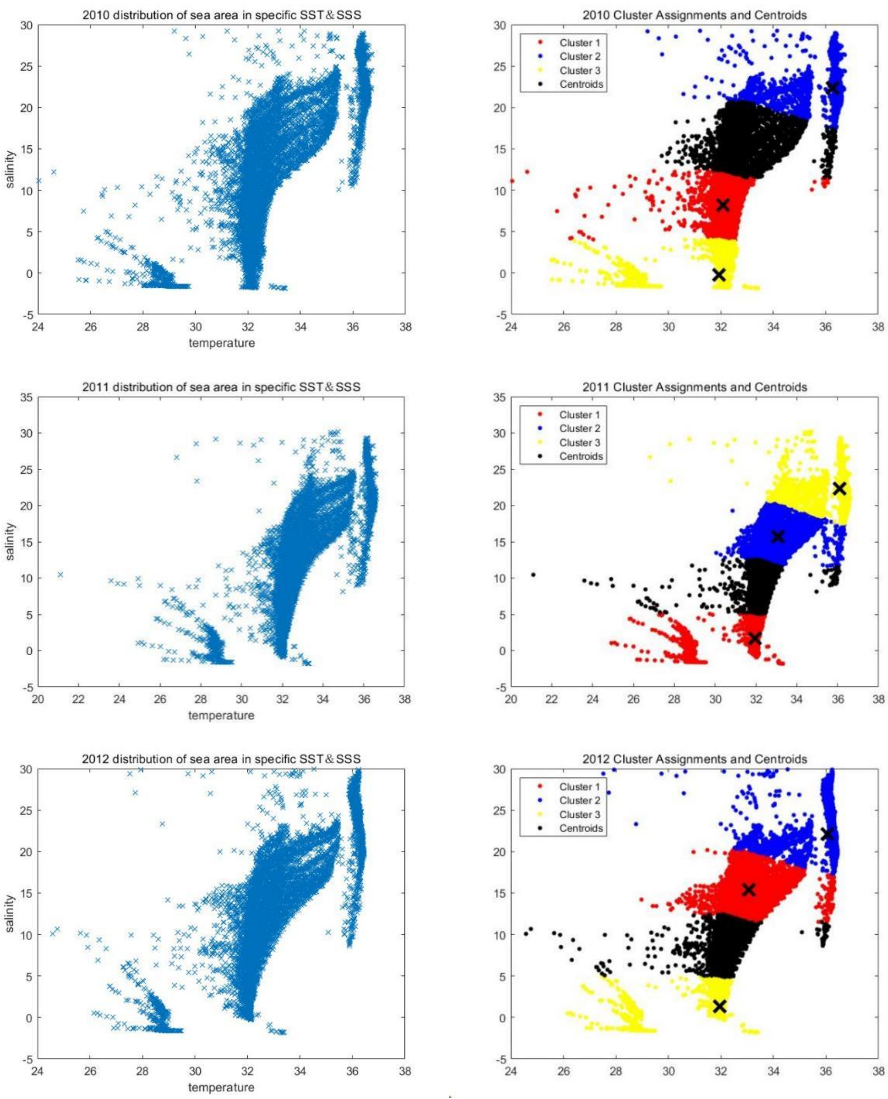
Note: (x, y) represent $(\overline{SSS}, \overline{SST})$.

$\overline{SSS}$: the mean value of SSS, $\overline{SST}$: the mean value of SST.

Table 1 showed there were no obvious fluctuations in $\overline{SSS}$ and $\overline{SST}$, and the team concluded that within five years, the sea surface temperature and sea surface salinity did not change and tended to be stable.

4.2. Classify the South Atlantic Ocean

Utilized method 1 to cluster the data, the researching team calculated the average range of SSS and SST of every cluster in the five years.



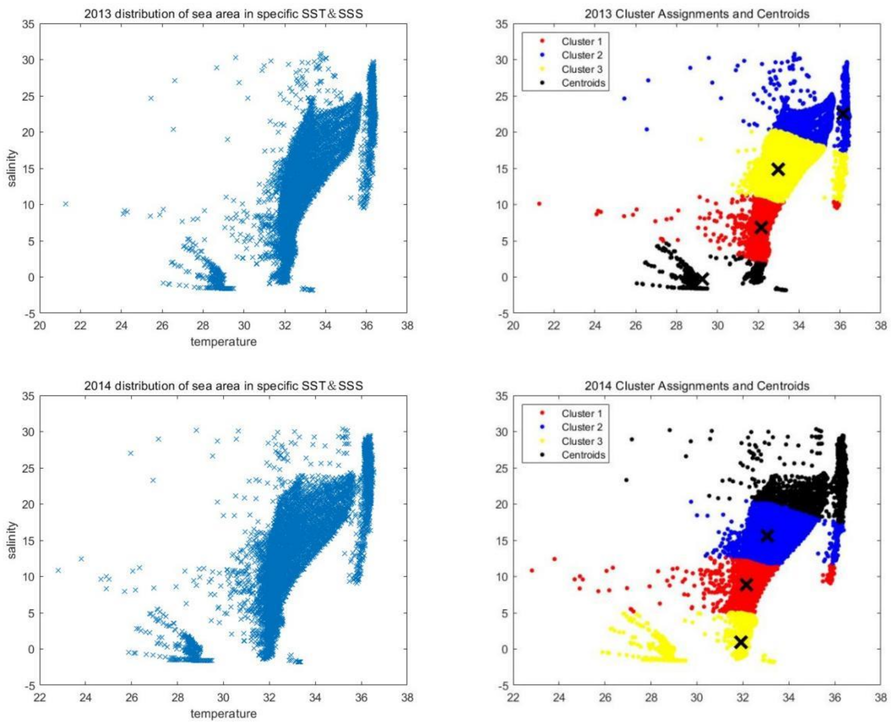


Figure 4. The position of 4 clusters and centroids in the graph of SSS and SST.

Based on the average SSS and SST range of each cluster, the corresponding regions were colored in the SSS and SST regional map. Figure 4 shows the variation of the position of each cluster within the five years and how the clusters were divided from the original distribution.

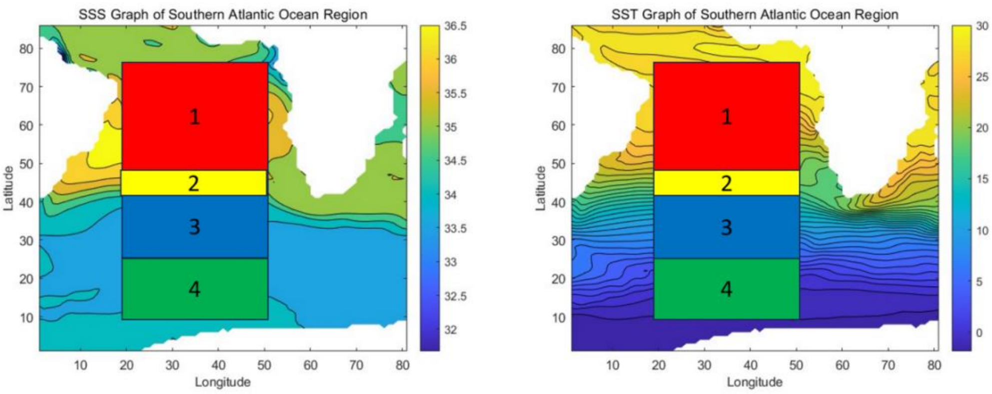


Figure 5. The position of 4 clusters in the map.

Finally, the team classified the South Atlantic Ocean into four clusters using five-year datasets. Each region has different features. Figure 5 shows that Region 1 (marked in red) has high temperatures and salinity. Region 2 (marked in yellow) has warm temperatures and high salinity. The third region (marked in blue) has moderate temperature and low salinity. Region 4 (marked in green) has the lowest temperature and mostly fresh water.

5. Conclusion

Overall, this study addressed the connection between SSS and SST in the southern Atlantic Ocean and its implications. This study had identified four different oceanographical regions in the aforementioned

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ocean area through the k-means clustering technique. Moreover, by examining the changes in the regional clusters from year 2010 to 2014, the research team concluded that their characteristics underwent no significant changes during the last five years.

This study is limited by the researchers' coding ability. The lack of proficiency in MATLAB had become a hurdle for the team to conduct the research. Equipped with better coding knowledge, this study could have concluded based on a more detailed and improved result. The time also sets up a limitation to the research. With only two weeks of time, the researchers decided the research question in a hurry. Once the result came out, the research team did not have sufficient time to assess the quality of clustering, such as using the silhouette function in MATLAB. Additionally, the research is built only on one of the datasets from the NASA database [10]. more datasets could provide a broader insight into the relationship of SST and SSS in the Southern Atlantic Region. Lastly, this study could inspire more research topics pertaining to the region. There could be research focusing on the rivers or glaciers that provide fresh water influx into the region and how that influences the SSS and SST. The Southern Atlantic region is also known as a place without the Inter-Tropical Convergence Zone, which often engenders tropical cyclones that might evolve into hurricanes, monsoons, and typhoons. Research could be done on examining such characteristics and their correlation with the SST/SSS trends in that region. Further researches could also investigate the change in SST/SSS trend in a longer time span because this research only looked at data from the year 2010 to 2014.

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