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Determine SST and SSS distribution and tendency of variation in the northern Atlantic Ocean using k-means clustering

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Abstract. Sea surface temperature (SST) and sea surface salinity (SSS) are crucial parameters in oceanographic research and have important implications for understanding the Earth's climate system, ecosystems, and global change. This paper will ascertain SSS and SST in the North Atlantic Ocean. Besides, K-means clustering was utilized to separate the data into several clusters once the data were installed in Matlab. According to the research results, the temperature dropped from the equator to the high northern latitudes. In contrast, salinity showed an initial increase and then a following reduction in trend. Despite rising temperatures and salinity, the region distribution of high SST and high SSS throughout the year remained mostly stable, but the area became larger. One of the regions with high salinity in North Africa has a strong connection to that is adjacent to the Mediterranean. The Earth's climate system includes essential elements, including SST and SSS, which are essential to the development and control of the climate. It's better to comprehend seasonal changes in climate patterns and long-term climate trends by investigating temperature and salinity.

Keywords: Sea surface temperature, Sea surface salinity, Mediterranean.

1. Introduction

Decadal to centennial climate variability has recently attracted a great deal of attention due to the need to distinguish between natural and human changes during the previous century, as well as an urgent interest in decadal cycles that have a direct impact on society, such as the Sahel drought or the U.S. Dust Bowl [1]. The system for forecasting and predicting atmospheric and oceanic conditions heavily relies on SST. It is used as boundary conditions for numerical weather prediction (NWP) and ocean forecasting models as well as to drive and constrain the exchanges of momentum, heat, moisture, and gas, the modeled upper-ocean circulation, and the upper ocean's thermal structure [2,3]. Another physical-chemical factor known as SSS plays a significant role in the Earth's climate and the density-driven global ocean circulation [4]. which is affected by freshwater fluxes, ice growth and melting, river runoff, horizontal advection, and vertical exchanges via mixing and entrainment [5-9]. Through its connections to the carbonate system, it also offers vital data for ocean biogeochemistry [10,11]. A spatial differentiation is required to describe and clarify time-dependent SST changes across the entire North Sea [12]. For figuring out the distribution, clusters were a useful tool. however, was not looked at, and SSS and SST in NA were not frequently examined using k-means clusters. Using k-means clusters with

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a particular amount of coding and a methodology provided, the study looked at the distribution of temperature and salinity in the North Atlantic Ocean over a 55-year period. Aside from that, we'll look into the causes of excessive salinity in North Africa. It is aware that rising salinity and high temperatures have an impact on marine ecology and conservation. SST and SSS are the most fundamental variables in physical ocean study since they are able to explain the most fundamental characteristics of seawater and aid in the understanding of turbulence, eddy currents, water mass mixing, etc. K-mean clusters used in this research is a significant breakthrough that will open new avenues of investigation for ocean researchers. Understanding how temperature and salinity are distributed can also benefit humanity by reducing global warming and promoting sustainable development.

2. Methodology

As shown in Figure 1, 4x4 data from the NASA CENTER FOR CLIMATE SIMULATION (NCCS) with the following coordinates: 288 longitude, 180 latitude, 12 months, and year 55s. provide SST and SSS information for the Atlantic and Pacific oceans in both hemispheres, all of which are kept in MATLAB. It randomly chooses data of SST and SSS for the first month and first year. Generated photos spread by different colors after taking the proper intervals in accordance with the data range.

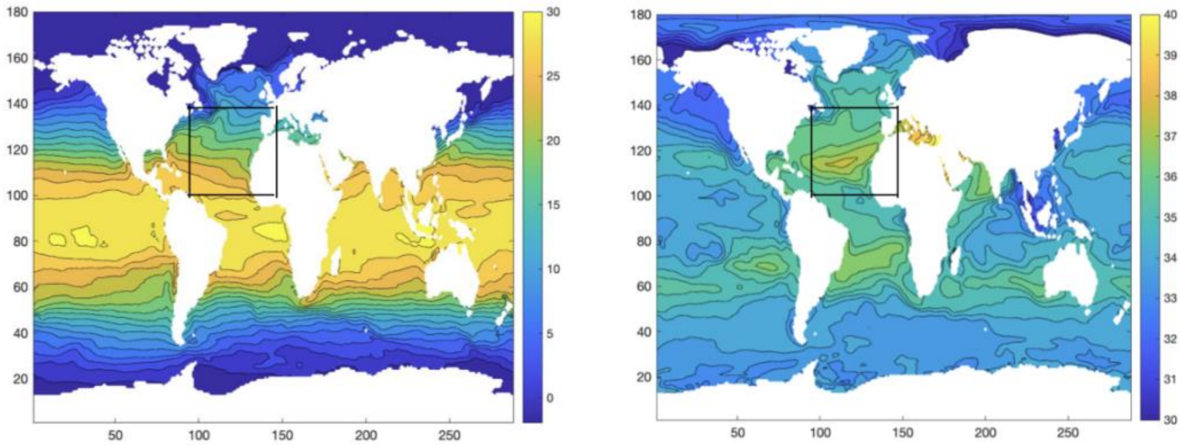

Figure 1. Sea surface temperature and salinity.

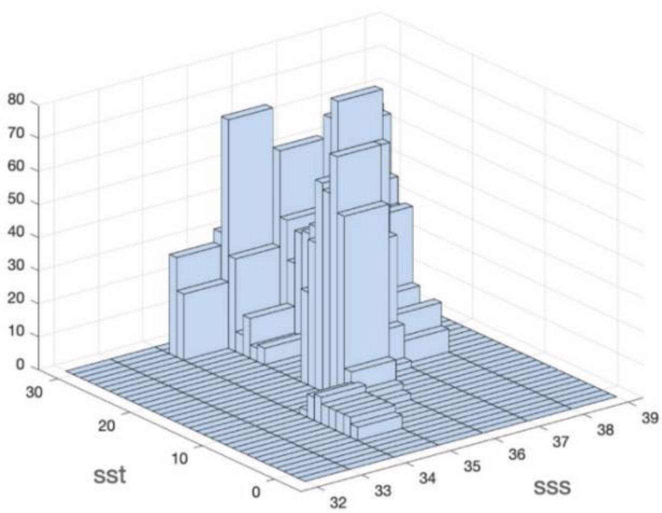

Figure 2. 2D histogram of sea surface temperature and salinity.

A specific area in the North Atlantic is chosen, lying close to the Mediterranean, with a latitude between 100 and 150 and a longitude between 100 and 140. The SSS and SST value range is computed

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using the max and min functions. The interval for SST and SSS has been chosen to be 1 in order to improve accuracy. Since the original data for SSS and SST are four-dimensional, dimensionality reduction is required. Longitude and latitude are multiplied to generate one dimension, month and year are multiplied to create the second dimension, and temperature and salinity are modeled independently. After the data has been reprocessed, a for loop that spans the whole year is used to construct two-dimensional histograms. Figure 2 reflects the SSS and SST in accordance with their horizontal and vertical coordinates. As a result, time series analysis may be used to examine the distribution and connection of these two variables. The rows and columns of the two-dimensional histogram are then rearranged into one-dimensional arrays.

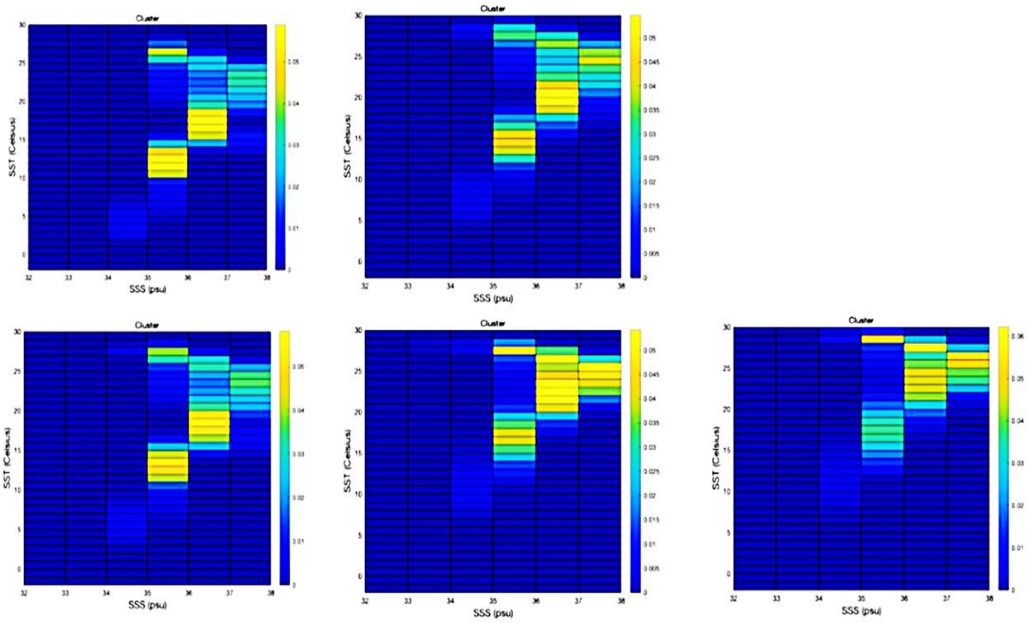

Figure 3. 5 clusters of sea surface temperature and salinity.

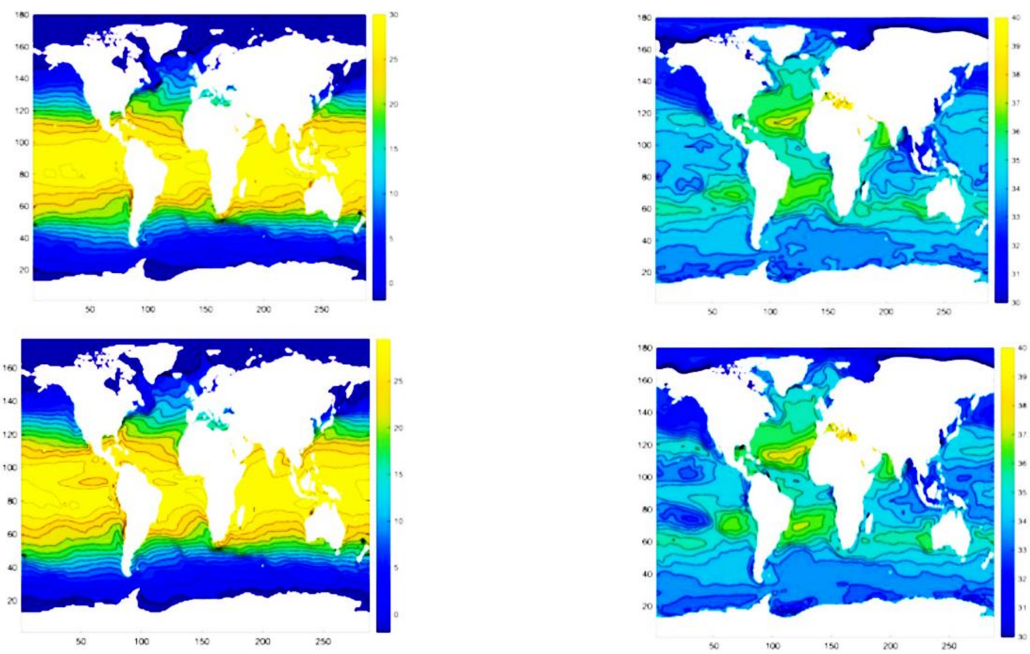

Figure 4. SST and SSS after 55 years(below) with Fig.1.

As shown in Figure 3, k-means clustering is used to separate the data into several groups. The number of iterations is set to 10, and the data is divided into five clusters. In order to organize each centroid C into a two-dimensional array of SSS and SST and optimize the center point, first calculate the distance between each data point and the centroid. The second loop is used to visualize each centroid in the next phase.

Figure 4 shows SST and SSS in January after 55 years and compares it with that 55 years earlier to further examine how SST and SSS change over time. The two upper graphs were SSS and SST before 55 years, and the two pictures on the bottom shared information after 55 years.

3. Results

Histograms help to observe how each point is distributed; k-means clustering is needed to separate the data into several groups in order to discover additional similarities and differences. The five clusters have divided the data of SSS and SST with the region latitude between 100 and 150 and longitude between 100 and 140. The data were primarily dispersed in regions with high temperatures and high salinity, with the exception of three that exhibited a generally similar distribution, which are the two clusters on the first line and the first cluster on the second line, but was nonetheless distinct. It is discovered that the North Atlantic has warmer zones nearer to the equator and colder regions farther from the equator, and there is a relatively uniform trend. Similar trends were seen in salinity, but there are still some extremely high salinity regions, like somewhere between the continents of Africa and North and South America. So, the distribution of salinity in the latitudes increases first and then decreases. When we examine the data 55 years later, the zones with high temperatures and salinity are still high. There are additionally more places of high salinity and a more consistent trend in temperature. However, there was also a marked increase in temperatures closer to the equator. The exterior round in yellow has grown larger, even though it is in a region with less salinity, like the ocean above the Mediterranean. There are still more places with high temperatures, even if the change in SST is not as significant as the change in SSS. The high-temperature zone has grown, and the temperature intervals have shrunk. In addition, it can be seen that unusually huge increases in temperature and salinity along the Mediterranean coast of North Africa over the 55 years.

4. Discussion

The salt levels in 1990 were not that extraordinary when compared to historical data going back to the early 1900s. However, the Great Salinity Anomaly (GSA) event’s magnitude was greater than the 1990 High Salinity Anomaly [13]. Since each cluster represents a different place, the five clusters are clearly distinguishable from one another, yet they are also frequently identical. It is because, with the exception of a few tiny regions around North African coasts, the North Atlantic does not fluctuate considerably. SSS fluctuates more than SST does, it is seen when comparing SST and SSS 55 years later, yet they both enlarge in areas with high temperature and salinity. Several sources provide evidence for the warmer Pliocene temperatures. In the Pliocene deposits from the coastal plain of the eastern United States, for instance, qualitative and quantitative analysis of ostracode assemblages and oxygen isotope data from molluscs show significant poleward displacement of faunal provinces and elevated temperatures in shallow marine environments [14-16]. Fir and spruce woods may be seen extending to the Arctic Ocean beaches during some of the Pliocene, according to paleontological records from Pliocene layers on Meighen Island in the Canadian High Arctic [17,18]. SST estimations obtained from diatom assemblages recovered at DSDP Sites 579 and 580 throughout the Pliocene provide evidence of periodic warming of surface waters of the Northwestern Pacific [19]. It follows that SSS is influenced by evaporation, precipitation, human activities, ocean currents, and clouds or winds are a few factors that contribute to SSS [20]. Given these facts, it is simple to understand why SSS exhibits a roughly decreasing trend. Salinity often decreases with increasing latitude, in part due to the activity of ocean currents, which transport saltier water to higher latitudes, and in part because of the region’s scorching summers, which considerably increase evaporation and induce excessive salinity. Two separate regions—North Africa coach and the Mediterranean—share a number of traits. For at least the last 40 years, the deep waters of the western Mediterranean Sea have been saltier and warmer at rates of roughly 0.015 and 0.04 °C every decade. Here, we demonstrate how two mechanisms are involved in these temperature and salinity rises. In harsh winters, deep water formation episodes convey more saline intermediate waters into the deep water on an interannual time frame. The Levantine Intermediate Water and the deep water are connected by a halocline-thermocline, which is the second phase. This process is characterized by a constant downward movement of heat and salt connected to salt finger mixing down via the halocline [21]. Due to its isolation and lack of direct access to the bigger sea, the Mediterranean Sea imports comparatively little fresh water and has a tiny number of rivers. In addition to having scorching summers, the region has significant evaporation rates. Water from the Mediterranean Sea ultimately becomes high salinity along the coast of North Africa as it continues to flow into the Atlantic Ocean [7].

5. Conclusion

This research focuses on the North Atlantic Ocean region, specifically with latitude between 100 and 150 and longitude between 100 and 140. Using Matlab and K-means clustering, we created images of Sea Surface Temperature (SST), Sea Surface Salinity (SSS), and their clusters. The clustering divided the region into five parts, revealing that areas with higher salinity tend to have higher temperatures. SSS showed a trend of initially increasing and decreasing from the equator to high latitudes, while temperature decreased from the equator to high latitudes. The region near the coast of North Africa exhibited high salinity due to the influence of the Mediterranean water. Over time, SSS fluctuated more than SST, but the overall pattern remained consistent, with zones of high salinity and temperature expanding. This research still has some limitations, such as the fact that we did not specifically analyze the specific regions of each cluster, and the Mediterranean region was not thoroughly surveyed. Besides, we only looked at the time dimension after 55 years, not narrowing the interval to observe changes in the interval. The study's contribution, though, is that marine ecosystems and climate trends may be predicted using both SST and SST data distributions. SST is a gauge of ocean temperature that directly affects the energy exchange between the ocean and the atmosphere. The evolution of extreme weather events like hurricanes, as well as wind and rainfall patterns, have all been profoundly impacted. Different species in marine habitats have varied responses to salinity and sea surface temperature, which affects the migration, reproduction, distribution, and life cycle of marine creatures. By clustering SSS and SST data values using k-clusting, scientists might discover evolving patterns like ocean warming, salinity shifts, and other climate trends. K-means clustering may be utilized in marine ecosystems to differentiate between distinct patterns and ecozones, pinpoint ocean locations with comparable salinity and temperature attributes, and get a deeper comprehension of the distribution and behavior of diverse biomes. Additionally, K-means clustering may be used to investigate the association between different SST and SSS trends and extreme weather events like hurricanes and tropical storms in order to better monitor and anticipate extreme weather occurrences.

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