Spatial distribution of variable density in the Gerlache and Bransfield straits during the austral summer between 1979-2019

Distribución espacial de la variable densidad en los estrechos de Gerlache y Bransfield durante el verano austral entre 1979-2019

DOI: 10.26640/22159045.2022.584 **Received:** 2021-12-27 / **Accepted:** 2022-09-20

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Citation:

Torres Ramírez, F. J. (2022). Spatial distribution of variable density in the Gerlache and Bransfield straits during the austral summer between 1979-2019. *Bol. Cient. CIOH;* 41(2): 3-16. Printed ISSN 0120-0542 and online ISSN 2215-9045. DOI: https://doi.org/10.26640/22159045.2022.584

Abstract

Colombia has carried out expeditions to the Antarctic since 2014, with the aim of contributing to knowledge about the white continent and materializing national interests in it. The present study contributes to the understanding of the oceanographic dynamics in the Gerlache and Bransfield straits from the joint analysis of temperature, salinity and pressure information collected with CTD equipment during the Antarctic expeditions carried out by Colombia between 2014 and 2019, complemented with 40-year data obtained from the World Ocean Database. This analysis allowed, through a prior quality control, to calculate and graph the horizontal distribution of the density variable at different standard depths during the austral summer between 1979 and 2019, in order to understand the distribution of this variable in the study area. The behavior of density was analyzed, demonstrating through the results that this parameter occurs due to variations in salinity and not in temperature, as occurs at low latitudes. Unlike previous studies carried out in the Antarctic Peninsula for a particular year, in the present investigation a period of 40 years of the southern summer (January, February and March) was selected, with a view to knowing the horizontal distribution of the variable density for different standard depths and to determine the expected conditions, which are an indicator of behavior at a general level in the study area.

Keywords: Antarctic Treaty, Gerlache, Bransfield, density, quality control, austral summer.

Resumen

Colombia ha realizado expediciones a la Antártica desde el año 2014 con el objetivo de contribuir al conocimiento sobre el continente blanco y materializar los intereses nacionales sobre el mismo. El presente estudio aporta al entendimiento de la dinámica oceanográfica en los estrechos de Gerlache y Bransfield a partir del análisis conjunto de información de temperatura, salinidad y presión recolectada con equipos CTD durante las expediciones antárticas realizadas por Colombia entre los años 2014 y 2019, complementada con información de 40 años obtenida del World Ocean Database. Este análisis permitió a través de un control de calidad previo, calcular y graficar la distribución horizontal de la variable densidad a diferentes profundidades estándar durante el verano austral entre 1979 a 2019, para así entender la distribución de la variable mencionada en el área de estudio. Se analizó el comportamiento de la densidad, demostrando a través de los resultados que, este parámetro se da en razón a las variaciones de la salinidad y no de la temperatura como ocurre en latitudes bajas. A diferencia de estudios previos realizados en la península Antártica para un año particular, en la presente investigación

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se seleccionó un periodo de 40 años del verano austral (meses de enero, febrero y marzo), con miras a conocer la distribución horizontal de la variable densidad para diferentes profundidades estándar y a determinar las condiciones esperadas, las cuales son un indicador de comportamiento a nivel general en el área de estudio.

Palabras claves: *Tratado Antártico, Gerlache, Bransfield, densidad, control de calidad, verano austral.*

Introduction

Colombia acceded to the Antarctic Treaty through Law 67 of 1988, with the aim of contributing to scientific research regarding phenomena with a global impact, such as global warming and climate change (Colombian Ocean Commission [CCO], 2018). This marked the beginning of the Colombian Antarctic Program (PAC) and the Antarctic Scientific Agenda 2014-2035, which plans to carry out seven expeditions to the white continent (CCO, 2014a), thus contributing to the future positioning of the country as a preponderant actor within the Antarctic Treaty System, and one which is taken into account for decision-making in that territory (Sánchez, 2018).

In this context, the generation and contribution of new knowledge becomes a fundamental input with a view to establishing baseline information for studies of oceanographic variables that serve as a reference for the different investigations that are conducted by scientists from all over the world on and around the Antarctic Peninsula. One of these variables is the density of seawater, which is directly proportional to its salinity and inversely proportional to temperature. Furthermore, considering that water is not very compressible, at great depths water is compressed and its density increases; Thus, the density of seawater is a function of salinity, temperature and pressure (Reyna *et al*., 2013).

Density variations correspond mainly to temperature variations, that is, the higher the temperature, the lower the density of seawater; however, in regions where the temperature is very low, such as in the polar regions, the density changes are due to variations in salinity (Reyna *et al*., 2013). Likewise, we can see that salt content causes the decrease in the freezing point of seawater to a temperature of approximately -1.8 °C. The density of a portion of seawater determines the depth at which it will be located in a water column. This density increases when the values of its salinity are higher or when the temperature decreases. In contrast, seawater is less dense when its salinity is heated or decreased by freshwater inputs, that is, by rivers or precipitation (Reyna *et al*., 2013).

Understanding the distribution of density in the study area allows for the determining of the behavior of this variable and its relationship with temperature and salinity; as well as the identification of masses of water according to their characteristics and, potentially to know the implications for the sonic signals of the study area.

The objective of this study is to contribute to the understanding of the spatial distribution of seawater density in the Gerlache and Bransfield straits during the austral summer, based on the analysis of thermohaline information obtained in the field during Colombian scientific expeditions to Antarctica (2014-2019) and global databases (1979-2019). This study is part of the Basic Knowledge of Oceanography, in the research project led by the General Maritime Directorate (Dimar), named the Marine Research for Maritime Safety in Antarctica (Iceman), which aims to develop marine research from the components of physical, chemical, geomorphological and hydrographical oceanography (CCO, 2014b). Likewise, it generates maritime education and scientific research, which are both maritime interests of Colombia, thus enhancing its participation in international scenarios.

Study Area

The northwestern tip of the Antarctic Peninsula is the closest part of the frozen continent to South America. This region is warming at some of the quickest rates on the planet, also leading to warming in deep and surface waters, and changes in other oceanographic variables such as salinity (Crespo, 2020). Climatic fluctuations during periods of atmospheric and oceanic warming have altered the dynamics of glaciers, and as a result, significant small- and large-scale losses of ice stocks have been observed in glaciomarine environments off the Antarctic Peninsula over the past few years (Hogg *et al.*, 2017).

The study area corresponds specifically to the Gerlache and Bransfield straits located off the coast of the Antarctic Peninsula, places where expeditions to Antarctica were carried out by Colombia (Fig. 1).

The Bransfield Strait is semi-enclosed between the South Shetland islands and the north coast of the Antarctic Peninsula. Its area is close to 50 000 km^2 and it can be divided into three large basins (García *et al*., 2002). The western basin of the strait is connected to the Bellingshausen Sea through the passages between the South Shetland islands and also through the Gerlache Strait, and to the Drake Passage mainly through the Boyd Strait. It extends approximately 300 km in a northeast-southwest direction, and its width varies between 60 and 100 km, and it is located between 62° S and 64° S, and from 55° W to 62° W (Zhou *et al*, 2002).

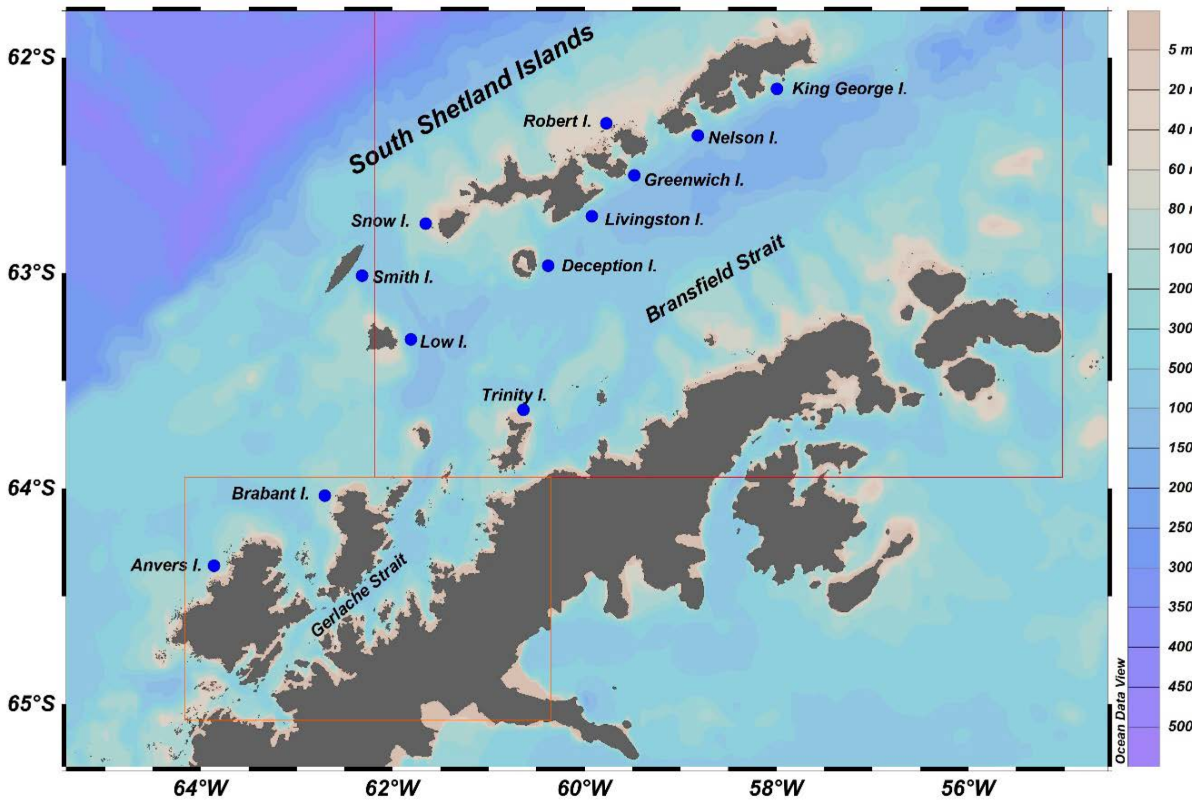

Figure 1. Gerlache Strait and Bransfield Strait near the Antarctic Peninsula.

The Gerlache Strait is located to the northwest of the Antarctic Peninsula, between latitudes 64° S and 65° S, and longitudes of 61° W and 64° W, delimited by the Palmer archipelago, which is dominated by the islands of Anvers and Brabant. The strait is 180 km long and 8 to 60 km wide, with a depth of 300 m at the southern end and 1 000 m at the northern end. It is characterized by being between islands, channels, shallow passes and fjords that lead to complex marine circulation, in addition to considerable atmospheric pressure and wind gradients that generate important surface currents. The surface circulation in the Gerlache Strait flows northeast with velocities greater than 30 cm/s feeding the Bransfield Strait current (Zhou *et al*, 2002).

Garcia *et al*. (2002), studied the water masses and the distribution of the physical-chemical properties in the Gerlache Strait and the western part of the Bransfield Strait during the austral summer of 1995-1996. These authors found that, to the east of the Bellingshausen Sea, there are four main water masses: Antarctic Surface Water (AASW), Upper Circumpolar Deep Water (UCDW), Lower Circumpolar Deep Water (LCDW) and Antarctic Bottom Water (AABW).

The AASW is a mass of cold water that originates around Antarctica at the beginning of winter and its depth is up to approximately 200 m. Below the AASW, there are two layers of circumpolar deep water (CDW), which differ in their origins. In the case of Antarctic Bottom Water, it is supplied by the Weddell Sea. In other words, the Bransfield Strait can be defined as a transition zone between the Bellingshausen Sea and the Weddell Sea. Thus, the aforementioned strait is occupied by masses of water whose properties are controlled by the characteristics of the inflows from the adjacent seas: a warmer flow from the Bellingshausen Sea, with a temperature between 0.5 and 3.0 °C and salinity between 33.1 and 33.9 psu in summer, and a cold flow with higher salinity coming from the Weddell Sea, normally characterized by negative temperatures and salinity values between 34.1 and 34.6 psu in summer (García *et al*., 2002).

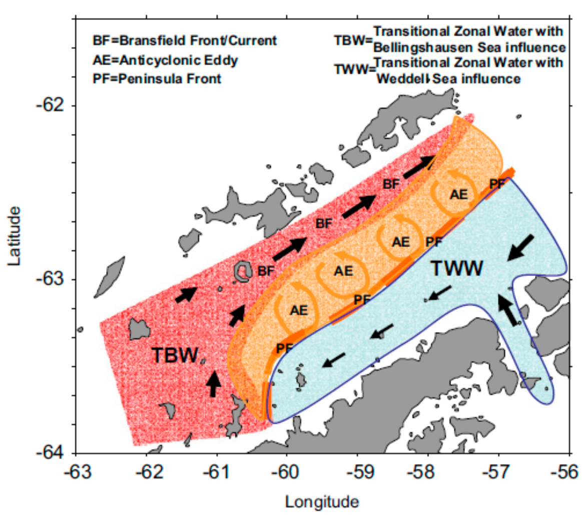

Figure 2. Dynamics in the Bransfield Strait (Source: Sangrà *et al*., 2011).

Garcia *et al*. (1994) indicated that in the Bransfield Strait, these two water masses can be referred to as Transitional Zonal Water with Bellingshausen Sea influence (TBW) and Transitional Zonal Water with Weddell Sea influence (TWW) depending on the waters where they originate. The TBWs appear to be confined to a strait in the mixed layer that extends along the northern half of Bransfield Strait; LCDWs flow into Bransfield Strait through the Boyd Strait and other passages, causing TWW to be replaced, producing deep temperatures above 0 °C (Fig. 2).

Garcia *et al*. (2002) determined that the Gerlache Strait can be understood as a westward extension of the western basin of the Bransfield Strait: The Gerlache Strait water column consists of an upper layer of TBW and an underlying layer of TWW. Lastly, they stated that limited CDW intrusions could occur from the west, between the TBW and the TWW in the Gerlache Strait; here the TBW must be colder and less saline than in Bransfield Strait due to freshwater inputs from local glaciers.

Using hydrographic data collected in the central basin of the Bransfield Strait in Antarctica, Sangrà *et al*. (2011) described the mesoscale variability, in which it was determined that the Bransfield Current flowed northeast along the slope of the South Shetland islands. Thus, a physical model suggested that the Bransfield Current behaves as a gravity current driven by local rotation rate and density differences between TBW and TWW. These same authors report that, below the Bransfield Front, a narrow 10 km wide stretch of CDW was observed along the slope of the South Shetland islands, and on the surface, the convergence of the TBW and the TWW leads to a shallow baroclinic front near the Antarctic Peninsula, called the Peninsula Front (Sangrà *et al*., 2011).

Consequently, the basic circulation pattern consisted of a flow from the west of relatively warm and fresh water from the Bellingshausen Sea, the Gerlache Strait and the Circumpolar Current, and an eastern flow of relatively cold and salty water from the Weddell Sea; the warm, fresh water flowed northeast along the northern half of the strait, while the cold, salty water flowed southwest along the southern half of the strait. They also deduced that the study area comprises waters that gradually change from those typical of the Bellingshausen Sea to those of the Weddell Sea (Sangrà *et al*., 2011).

Based on an oceanographic study and observation of the environmental conditions of the Bransfield Strait, Vásquez and Tenorio (2016) concluded that, in the aforementioned strait, there are three types of water: that of the Weddell Sea, water of the Bellingshausen Sea characterized by the presence of AASW, and CDW waters of the Gerlache Strait. Likewise, they found that there is a marked separation between the warm and less saline waters that flow northeast in the northern half of the Bransfield Strait, and the cold and saline waters that occupy its southern half.

In this same study, it was determined that the lowest temperatures occur close to the Antarctic Peninsula due to the cold waters coming from the Weddell Sea; while the highest surface temperatures were recorded near the South Shetland islands, possibly due to the advection of warmer waters (Vásquez and Tenorio, 2016). Along the central axis of the strait, they identified the presence of a thermal and haline front, called the Bransfield Front, which was associated with a baroclinic jet stream, preserving the north-south difference: that is, a warm north and cold south (Vasquez and Tenorio, 2016).

Recently, Torres, Caicedo and Iriarte (2020) described the hydrographic conditions during the austral summers of January 2015 and 2017 for the Gerlache and Bismarck straits located north of the Antarctic Peninsula, in which it was possible to determine that the temperature of the mixed layer during January 2017 was warmer than in previous years, while there was an severe decrease in Antarctic Sea ice extension in late 2016.

Methodology

This research used temperature, salinity and pressure data obtained during the Antarctic expeditions carried out by Colombia between 2014 and 2019 and recorded with an SBE-19 Pro V2 profiler CTD-O and two Sea-Bird 25T CTD-Os, which are provided for scientific use by the Colombian Oceanographic Data Center (Cecoldo).

The study also used the data available in the World Ocean Database (WOD) from 1979 to 2019 in the study area. Based on this data, the density variable was calculated in the study area following the methodology proposed by UNESCO, using the SEAWATER package. For this, we used TEOS-10 which, through absolute salinity and conservative temperature, allowed for the determination of the density for each standard depth in the study area (McDougall and Barker, 2011).

Finally, to draw the density graphs, Ocean Data View (ODV) software was used by applying the DIVA (Data-Interpolating Variational Analysis) interpolation method, which allows for the interpolation of data that is not regularly spaced. The phases followed during the methodological approach are explained in detail below.

Phase 1: Data processing

To guarantee the quality control of the data obtained from the WOD and Cecoldo, the international methodology proposed in the preparation of the World Ocean Atlas 2018 (García *et al*., 2018) was followed. The data processing was carried out using a code developed using MATLAB software, with a view to processing the data to guarantee quality control, including the functions of the TEOS-10 for the calculation of density. Quality control began with the removal of rows with erroneous data, removal of data outside the range of the study area, and selection of data at standard depths. Then, data outside the historical ranges were removed (Table 1) (García *et al*., 2018).

Table 1. Values of historical maximum and minimum ranges (Source: García *et al*., 2018).

Depth. (m)	Temperature (°C)		Salinity	
---	Minimum	Maximum	Minimum	Maximum
1	-2.40	15	0	40
10	-2.40	15	26	36.75
20	-2.40	15	28	36.75
30	-2.40	15	29	36.5
50	-2.40	15	30	36.5
75	-2.40	15	30.5	36.5
100	-2.40	15	30.5	36.5
125	-2.40	15	30.5	36.5
150	-2.40	15	31	36.5
200	-2.40	15	31	36.25
250	-2.40	15	31	36

Depth. (m)	Temperature (ºC)		Salinity	
---	Minimum	Maximum	Minimum	Maximum
300	-2.40	15	31	36
400	-2.40	15	31.5	35.75
500	-2.40	15	32	35.50
600	-2.40	10	33	35.50
700	-2.40	10	33.8	35.25
800	-2.40	10	33.8	35
900	-2.40	10	34	35

Subsequently, we applied the "Excessive gradient or inversion check" filter (Eqn. 1), which, according to Romero, Marriaga and Torres (2007), refers to an excessive decrease or increase in the value of the parameter with respect to depth; the gradient is usually a negative value and an inversion a positive value.

$$Gradient/Inversion = \frac{V_2 - V_1}{Z_2 - Z_1} \qquad \textbf{(Eqn. 1)}$$

Where V_1 is the value of the variable at the depth of the current level, V_2 is the value of the variable at the next depth level, Z_1 is the depth in meters of the current water level, and Z_2 refers to the depth in meters of the next level. Similarly, Garcia *et al*. (2018) determined the values from the trends of each variable, both for the gradients (Maximum Gradient Value - MGV), and for the inversions (Maximum Inversion Value - MIV) (Table 2).

Table 2. Maximum gradient and inversion factors used by WOD18 (Source: García *et al*., 2018).

Parameter	Depths up to 400 m		Depths greater than 400 m	
	MIV	MGV	MIV	MGV
Temperature	0.300	-0.700	0.300	-0.700
Salinity	9.000	-9.000	0.050	-0.050

For the following quality control, called "statistical controls", the entire study area was divided into 44 cells of 0.3° latitude by 0.6° longitude, with a view to achieving better resolution and thus obtaining greater detail, while also reducing the deformation of the grid due to the cartographic projection used (Transverse Mercator) for high latitude areas (Fig. 3).

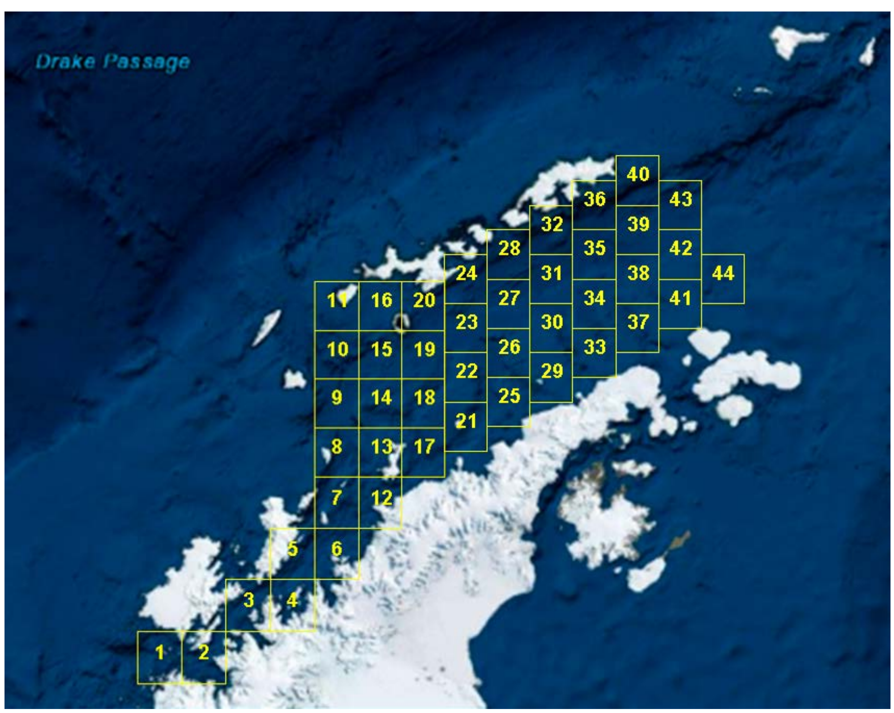

Figure 3. Division of the study area by cells (Source: Lara and Jiménez, 2019).

With the filtered data, an average was calculated for the temperature and salinity variables at standard depths in each cell over the data range of 40 years, from 1979 to 2019. This was calculated for the austral summer, that is, the months of January, February and March. Likewise, "Six Sigma (6σ)" quality control was applied, which consisted of eliminating the values that are more than three standard deviations above or below the mean (Z>3 or Z<-3), as they represent high noise and are not reliable (Santamaría-del-Ángel *et al*., 2019).

After the data was subjected to the indicated treatment to guarantee optimal quality control, it was assigned a quality flag in accordance with the provisions of García *et al*. (2018), where the data that m*et al*l the filters was assigned a "0" flag. This ensured that the data met the minimum quality standards required by the scientific community and could be considered reliable information.

Phase 2: Variable Density Calculation

Once the filtered temperature and salinity data was obtained, a TEOS-10 computer package was used, from which the density value was obtained at each standard depth and for each cell. TEOS-10 takes into account the effects of variations in the composition of seawater throughout the world's oceans that generate density differences (McDougall and Barker, 2011). According to these authors, the calculation of the density must be made based on the absolute salinity, conservative temperature and pressure (Eqn. 2); the absolute salinity was calculated using the practical salinity, pressure, latitude and longitude; the conservative temperature was calculated based on absolute salinity, temperature and pressure.

$$\rho = \rho\,(SA, CT, p) \qquad \textbf{(Eqn. 2)}$$

Phase 3: Variable Density Graphs

Finally, to obtain the graphs of the density variable, we used ODV version 5.4.0. (March 2021) software, which is freely accessible. This software allows for the analysis and visualization of a large number of oceanographic variables, time series, and data sequences, among other features (Ocean Data View, 2021). ODV uses the DIVA interpolation method, which, according to Troupin *et al*. (2012), is a method that allows for the interpolation of data that is not regularly spaced, taking into account the background and the borders of the study area. This method was used in the elaboration of the Atlas of Oceanographic Data of Colombia 1922 - 2013 (Andrade, Rangel and Herrera, 2015), which, according to the authors, has been successfully applied in various oceans and at different scales.

Results

Below, 12 graphs of the horizontal distribution of the density variable in the study area at different depths are shown, corresponding to the austral summer. In Figure 4 a mosaic of the horizontal distribution of density for depths of 1, 10, 20 and 30 m can be seen. The horizontal distribution of density in the study area presents greater variability on the surface (Fig. 4a), compared to the other depths, showing values of between 1 025 and 1 034 kg/m^3. At a depth of 10 meters (Fig. 4b), high density values are evident in the southern part of the Bransfield Strait, and lower values in the northern part. As the depth increases, the density values increase, and the range decreases; for example, while at a depth of 10 m the density oscillates between 1 026 and 1 027.8 kg/m^3, at a depth of 30m there are values between 1 027.3 and 1 027.8 kg/m^3.

A similar behavior can be observed in Figure 5, which corresponds to the density distribution at depths of 50, 75, 100 and 125 m, in which it can be seen that the density is higher in the southern part of the area of study and lower in the northern part.

As depth increases, the density values increase, and their range is maintained; For example, in the 50 m graph (Fig. 5a), the density oscillates between 1 027.5 and 1 027.9 kg/m^3 and at 125 m, values between 1 028 and 1 028.4 kg/m^3 are presented (Fig. 5b). Additionally, at depths of 100 and 125 m, a well-defined high-density core can be seen to the south of King George Island, with values of 1 028.3 and 1 028.4 kg/m^3, respectively (Fig. 5c and d).

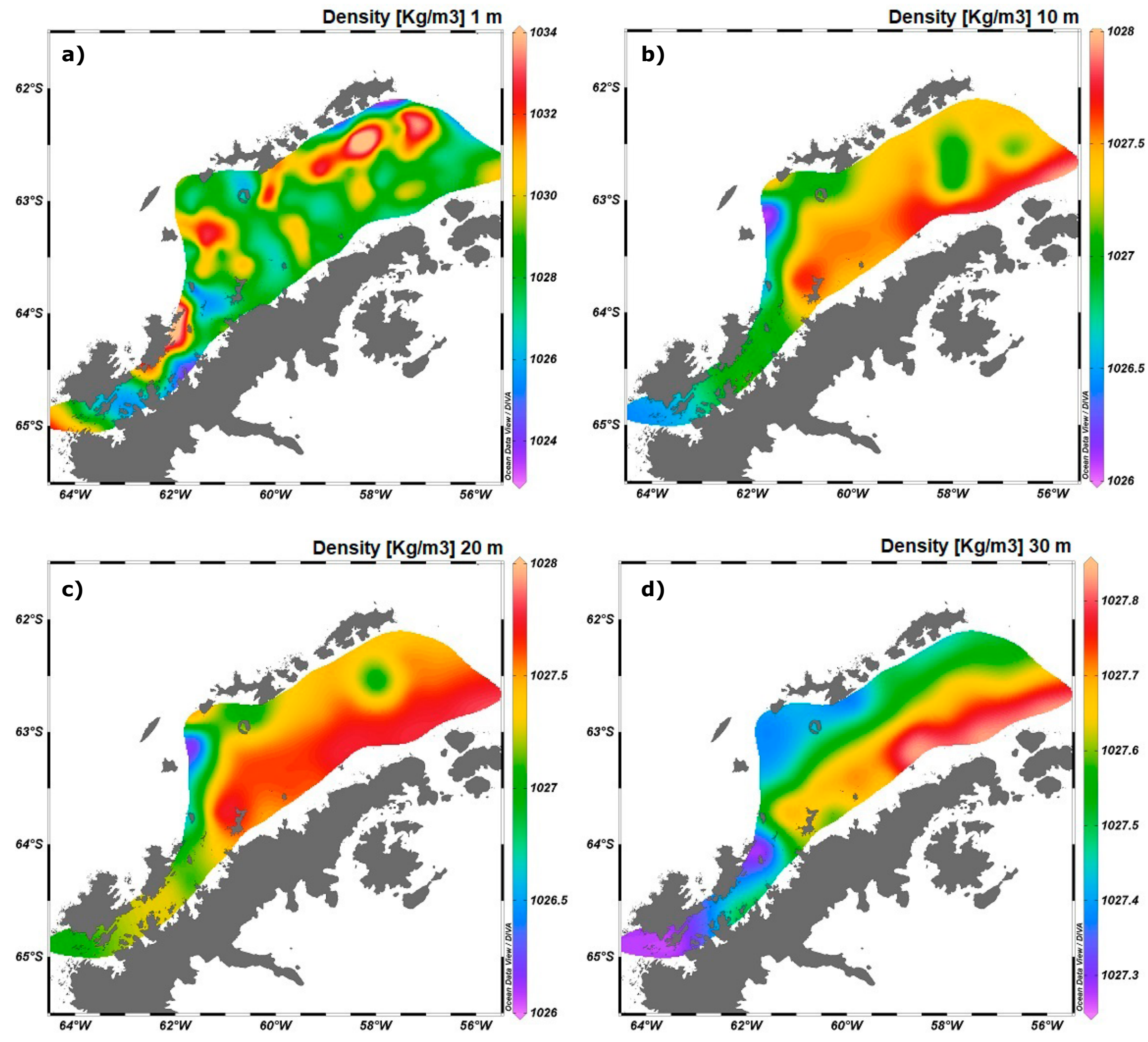

Figure 4. Distribution of density in the study area at depths of (a) 1 m, (b) 10 m, (c) 20 m and (d) 30 m.

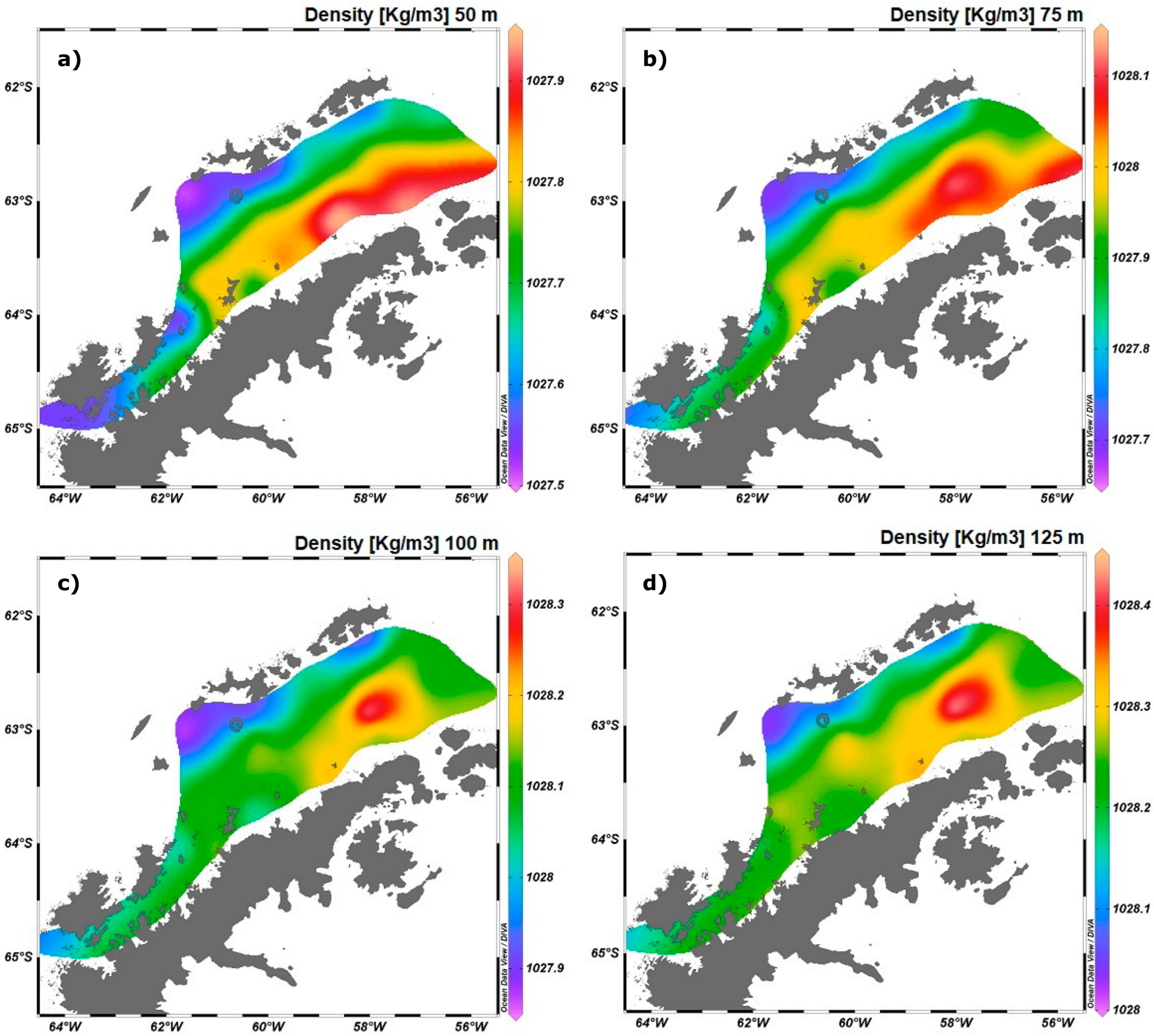

Figure 5. Distribution of density in the study area at depths of (a) 50 m, (b) 75 m, (c) 100 m, and (d) 125 m.

In Fig. 6 the behavior of the density is ascertained for depths of 150, 200, 300 and 400 m; it shows high densities in the southern part of the strait and low values in the northern part. As the depth increases, the density values increase, and the range decreases; for example, at 150 m (Fig. 6a), the density oscillates between 1 028.2 and 1 028.5 kg/m^3, and at 400 m, between 1 029.6 and 1 029.75 kg/m^3 (Fig. 6d).

Likewise, the graphs corresponding to the horizontal distribution of density in the study area at 150 and 200 m (Fig. 6a and b), show that the high-density nucleus to the south of King George Island is no longer so well defined and begins to have a greater influence in the study area, with a density of 1 028.5 and 1 028.75 kg/m^3, respectively.

In the 300 m graph (Fig. 6c), there is evidence of a lesser presence of water from the Weddell Sea, which enters from the northeast and circulates to the southwest of the Bransfield Strait. In the 400 m graph (Fig. 6d), the highest density values of all the graphs are presented, oscillating between 1 029.6 and 1 029.75 kg/m^3, but with the smallest range (0.15 kg/m^3).

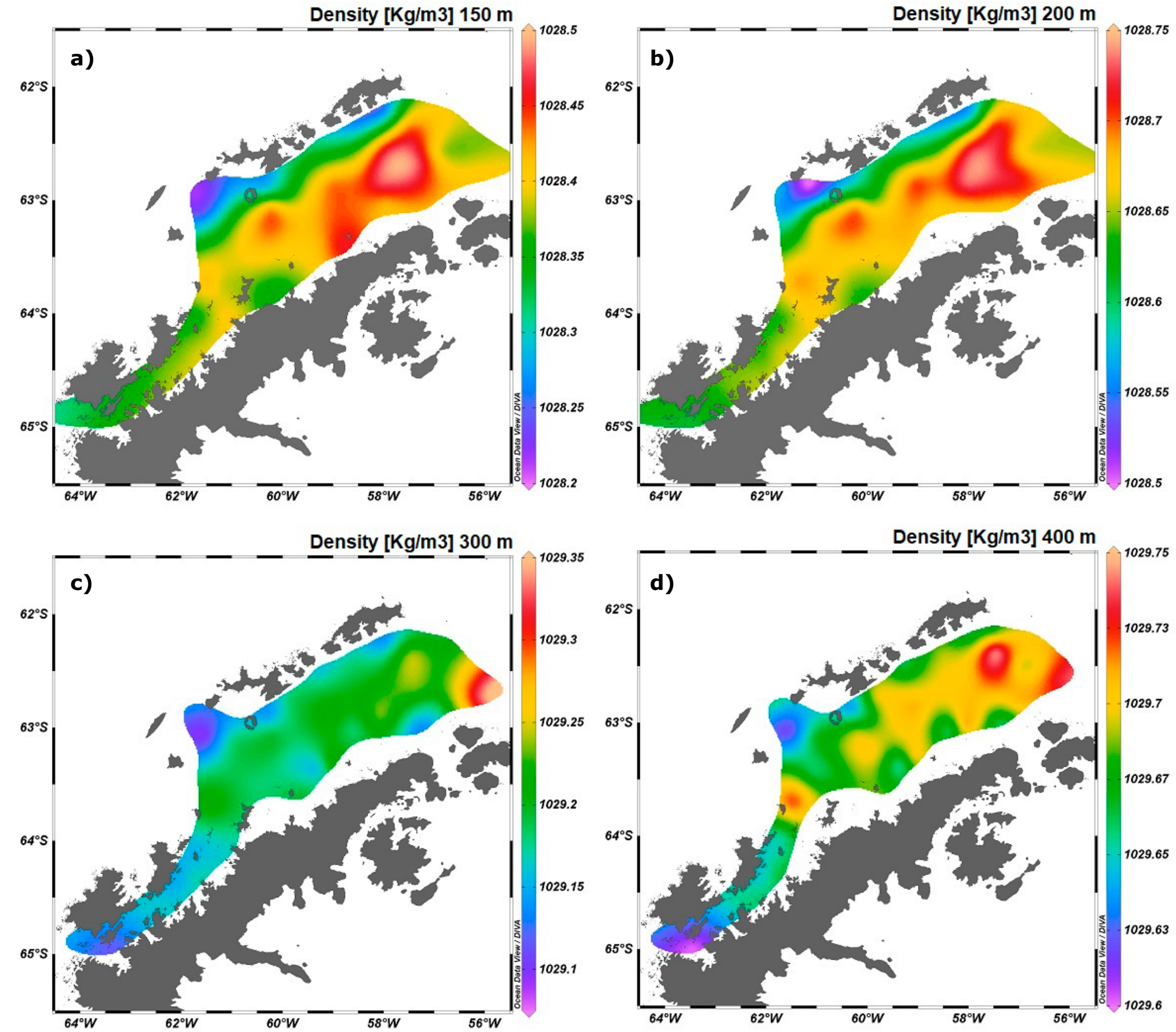

Figure 6. Distribution of density in the study area at depths of (a) 150 m, (b) 200 m, (c) 300 m, and (d) 400 m.

Finally, it was identified that starting at a depth of 10 m (Fig. 4a), the density in the Gerlache Strait increases as the pressure increases, however, the density values are lower compared to the values that are shown in the distribution of that parameter in the rest of the study area.

Discussion

From the analysis of the different depth layers (Fig. 4, 5 and 6), it was possible to determine that the greatest variation and intervals in density occur at the surface (Fig. 4a). According to Torres, Caicedo and Iriarte (2020), this is due to the interactions between atmospheric air, ocean and ice in the region. Additionally, AASW is the most common water in the surface layer of the Antarctic Peninsula, with a wide range of temperatures and salinities.

In general, in all the graphs, two bodies of water can be seen, one of greater density and the other of lesser density. This was observed by Sangrà *et al*. (2011), who identified two water flows with different characteristics: one influenced by the Bellingshausen Sea which flows from the west of the strait, with warm, fresh and less dense water, and another cold, salty and dense flow influenced by the Weddell Sea which flows from the east.

On the other hand, from 30 m (Fig. 4d), we can see that the density begins to increase as the depth increases. Rodrigo *et al*. (2021) mentioned that the density variable begins to gradually increase from 40 m depth, and that difference of 10 m does not seem significant.

In Figures 4, 5 and 6, the density presents a behavior similar to that of salinity. According to Curry and Webster (1999), salinity is more important than temperature in regulating density at the poles; therefore, any surface profile will be less changeable than at mid- or low-latitudes. Likewise, Reyna *et al*. (2013) mentioned that in regions where the temperature is very low, such as in the polar regions, the changes in density are due to variations in salinity. This density increases when the value of its salinity are higher or when the temperature decreases.

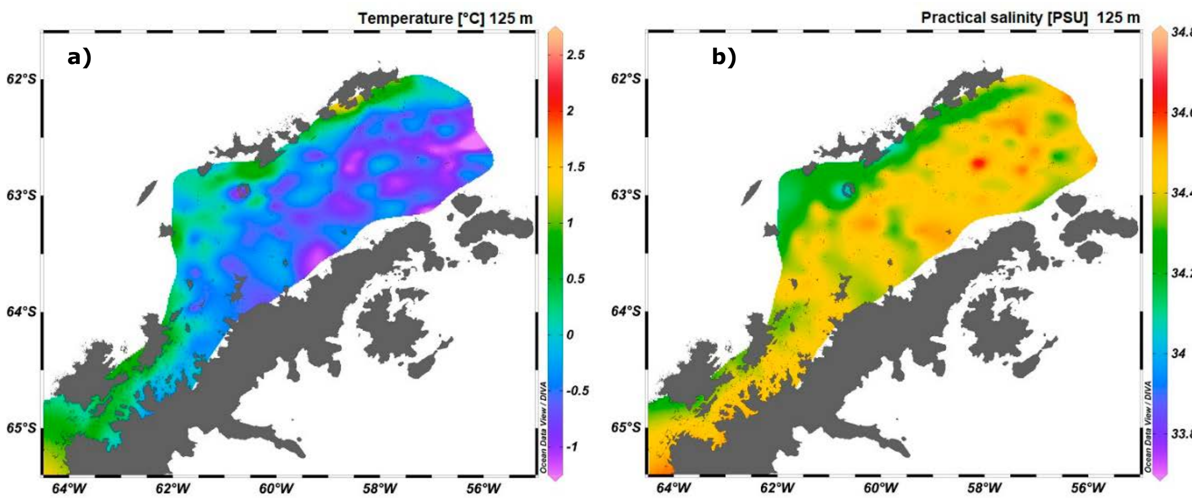

Figure 7. Chart showing horizontal distribution of (a) variable temperature and (b) salinity in the Bransfield and Gerlache Straits, at a depth of 125 m (Source: Lara and Jiménez, 2019).

In the graphs for 100 and 125 m depths (Fig. 5c and d) and 150 and 200 m depths (Fig. 6a and b), a high-density core can be seen south of King George Island. These density nuclei are related to the colder and saltier waters of the Weddell Sea, demonstrating that the highest density in the study area occurs in the Antarctic Peninsula (Vásquez and Tenorio, 2016). Likewise, in the salinity results at 125 m from Lara and Jiménez (2019), a salt core can be seen to the south of King George Island, as well as a lower temperature in the same area (Fig. 7), demonstrating a direct relationship with the high-density nuclei that can be seen in the aforementioned density graphs.

Nevertheless, in Fig. 6c, corresponding to the horizontal distribution of density in the study area at 300 m, this is where waters of the Weddell Sea have the least influence. Garcia *et al*. (2002) stated that limited CDW intrusions may occur from the west of the Gerlache Strait between 250 and 450 m depth, that is, there is a greater predominance of TBW. However, in the graph corresponding to 400 m (Fig. 6d), a greater influence of Weddell Sea waters in the Bransfield Strait is again evident, that is, high density values, which indicate cold waters and higher salinity. This is related to what was described by García *et al*. (2002), who note that the Antarctic Bottom Water is contributed by the Weddell Sea.

In the Gerlache Strait, it was observed that the densities for each standard depth, in general, were lower values compared to the others obtained in the Bransfield Strait. According to Garcia *et al*. (2002), TBWs in the Gerlache Strait are cooler and less saline than in the Bransfield Strait due to freshwater inputs from local glaciers.

By superimposing the graph of the horizontal distribution of density in the study area onto the graph of the strait dynamics of the Bransfield

Strait currents determined by Sangrà *et al*. (2011) (Fig. 8), an association between water bodies with different densities and water flows with different characteristics is evident: one influenced by the Bellingshausen Sea which flows from the west of the strait, and another, influenced by the Weddell Sea which flows from the east (Sangrà *et al*., 2011).

Additionally, between the Bransfield Front (northern stream) and the Peninsula Front (southern stream), according to Sangrà *et al*. (2011), a system of anticyclonic eddies with TBW characteristics was observed, extending from the surface to a depth of 400 m, and with a radius of approximately 10 km. This eddy signal that reaches depth can be seen in the density distribution graphs from 30 to 200 m, as a green line along the study area which separates the TBW and the TWW.

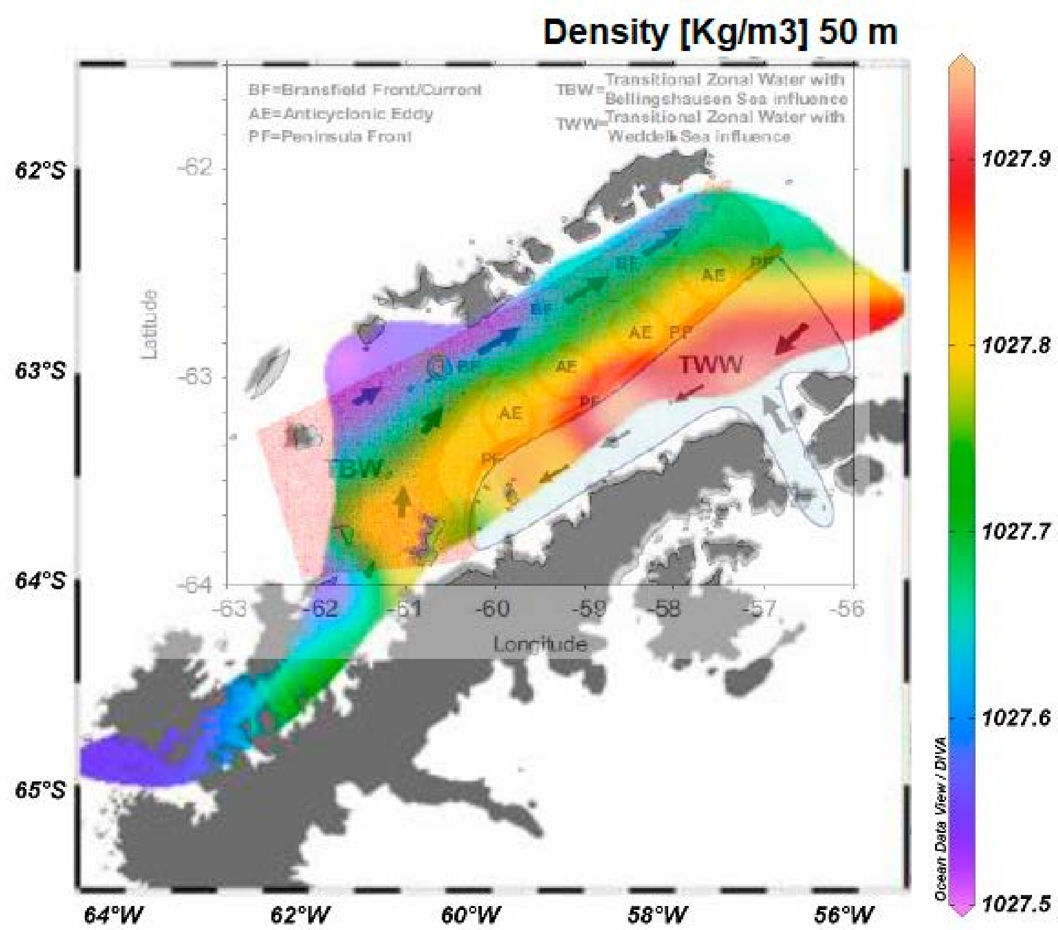

Figure 8. Chart showing horizontal distribution of the temperature and salinity variables in the Bransfield and Gerlache Straits, at a depth of 50 meters, superimposing the image of the dynamics of the study area proposed by Sángrà *et al*. (2011).

Conclusions

12 graphs corresponding to the average austral summer density were generated at different standard depths of between 1 and 400 m. In general, the behavior of density is similar to that of salinity for each standard depth, taking into account that at the poles this variable has a greater influence on density, rather than temperature as occurs at other latitudes.

Analysis by layers at different depths allowed the identification of bodies with different density values, which correspond to the water masses described by García *et al*. (2002), whose properties are controlled by the characteristics of the adjacent inflows: a warmer, less saline and lower density flow from the Bellingshausen Sea, and a colder, more saline and denser flow from the Weddell Sea; the first enters the study area from the south and the second enters from the northeast, respectively. Density responds more to salinity than temperature in this case.

As in the Bransfield Strait, in the Gerlache Strait the density presented greater oscillations on the surface, showing values of between approximately 1 025 and 1 033 kg/m^3; from 10 m deep, the density increases progressively as the depth increases.

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