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AN ATTEMPT TO DETERMINE THE DYNAMICS OF WATERS IN THE REGION OF INTERACTION OF THE BRAZIL AND FALKLAND CURRENTS

1. INTRODUCTION

A convergence zone of sea currents in the form of the Subtropical Convergence occurs in the surface layer of south-west Atlantic. The warm, saline waters of the Brazil Current flow from the north along the coast of South America. At the beginning of winter, i.e. from May to July, the direction of this current is roughly steady, the constancy ranging from 25 to 50 per cent. In the in-shore zone, the greatest disturbances of the Brazil Current occur due to the expansion of the cold waters of the Falkland Current northwards, particularly during the winter season, i.e. from May to October. During this period the Brazil Current deviates off the coast of the continent due to the inflow from the south of cold, low saline waters, called the Brazil Coastal Countercurrent which can be classified as a seasonal extension of the Falkland Current. This phenomenon usually commences in April and flows quickly to 24°S in May and June [4]. Owing to this phenomenon, to the south of this parallel the Brazil Current waters are carried away from the coast of America, first SE and then E.

The masses of the surface water flowing eastward with the waters of the Falkland Current, here from the South Atlantic Current constituting the northern part of general eastern circulation refered to as the West Winds Drift [5]. This circulation regime of sea currents together with the survey area is shown in Fig. 1. Summing up, there are two water circulation systems: the surface system where the transport of water is mainly thanks to permanent winds, and another system which embraces the remaining part of the ocean, where the movement of water masses is mostly due to differences in density. These two commonly-known systems merging in the region of the Subtropical Convergence cause intensive mixing of the water bodies and the anticyclonic South Atlantic Gyre observed on the surface, reach down to a depth of at least 2000 m [2].

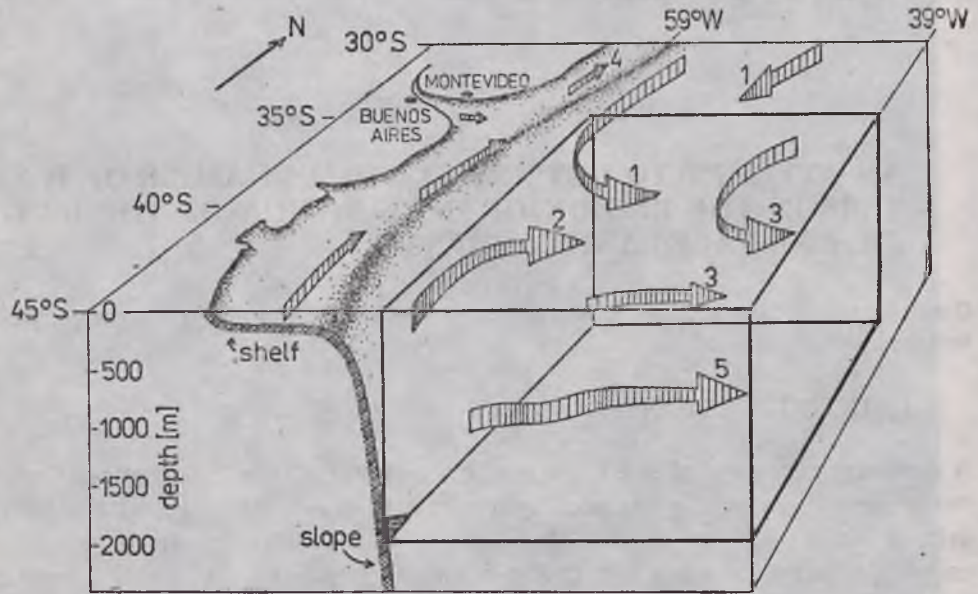

Fig. 1. Idealized model of three-dimensional circulation driven by currents system in the Argentine Basin.
1 — Brazil Current, 2 — Falkland Current, 3 — South Atlantic Current, 4 — Brazil Coastal Countercurrent, 5 — West Winds Drift

Rys. 1. Wyidealizowany model cyrkulacji przestrzennej wymuszonej układem prądów w Basenie Argentyńskim.
1 — Prąd Brazylijski, 2 — Prąd Falklandzki, 3 — Prąd Południowego Atlantyku, 4 — Brazylijski Przeciwprąd Przybrzeżny, 5 — Dryf Wiatrów Zachodnich

2. MATERIAL AND METHOD

The material was analysed on the basis of data from 46 oceanographic stations situated in the south-west Atlantic, in the region of the Argentine Basin determined by the following co-ordinates: from 39°W to 59°W and from 35°S to 45°S. Thus, the stations covered an area of 1,082,000 km², measurements being taken to a depth of 2000 m in each case. The stations were distributed along 5 meridional profiles, so that an area of the ocean in the form of a prism not reaching to the bottom was surveyed. The survey was carried out from 4th to 30th May, 1978. Measurements of hydrological elements were carried out at each station using Nansen bottles at standard levels beginning from 200 m downwards. In a layer extending from the surface down to a depth of 200 m, the measurement levels were established after analyzing the temperature records from the bathythermograph. The temperature of the sea water was measured by reversible thermometers with an accuracy of ±0.01°C, the potential temperature then being calculated.

The salinity of the sea water was measured with an Autolab Model 601 salinometer with an accuracy of ±0.003‰. Further calculations of all the dynamic parameters were carried out on an Elliot 905 ship-borne computer based on programmes written by mgr inż. Alfred Grelowski from the Sea Fisheries Institute, Gdynia.

For the sake of simpler graphic representation of the hydrodynamic processes, the prism was replaced by a cuboid.

3. RESULTS

In order to present the movement of waters, dynamic heights were calculated in dynamic millimeters which formed a system of isobars when entered onto the charts. The concentration of these iso-lines is proportional to the velocity of geostrophical currents at particular latitudes. The southern part of the prism was analysed in the zone between 40°S and 45°S and the layer from 0 to 1500 m, i.e. frontal zone of interaction of the Brazil and Falkland Currents. Three maps of the dynamic topography were drawn up at 0,200 and 800 db with reference to the 1500-db surface and a fourth one of the water circulation at the 1500 db level with reference to the 2000-db level (Fig. 2).

It should be pointed out that the choice of the reference surface is very important from the point of view of further considerations (quantitative in particular), as the surface represents a plane where the horizontal movement of water bodies is theoretically non-existent. Of course, there is no such homogeneous surface over the area of more than 1 million km² in the ocean. For this reason, in the selecting of such a reference surface, in this paper, use was made of the available literature (analysis of all hydrochemical parameters) and the fact that the Brazil Current in the investigated part of the Argentinian Basin is commonly refered to as the flow of waters southwards above approx. 1500 db, whereas deeper waters with the thermal and oxygen minima are of different origin. Another reason for this choice of the 1500-db reference surface was the fact of a similar location with respect to the third maximum of the hydrostatic stability, here marking the water masses of the Antarctic Intermediate Water and upper branch of Circumpolar Water [2]. The iso-lines of the dynamic heights run in accordance with the spatial distribution of all hydrological elements. The greatest concentration of isobars occurred on the border-line between two local countercurrent rings: an anticyclonic with its centre lying on the A axis and a cyclonic

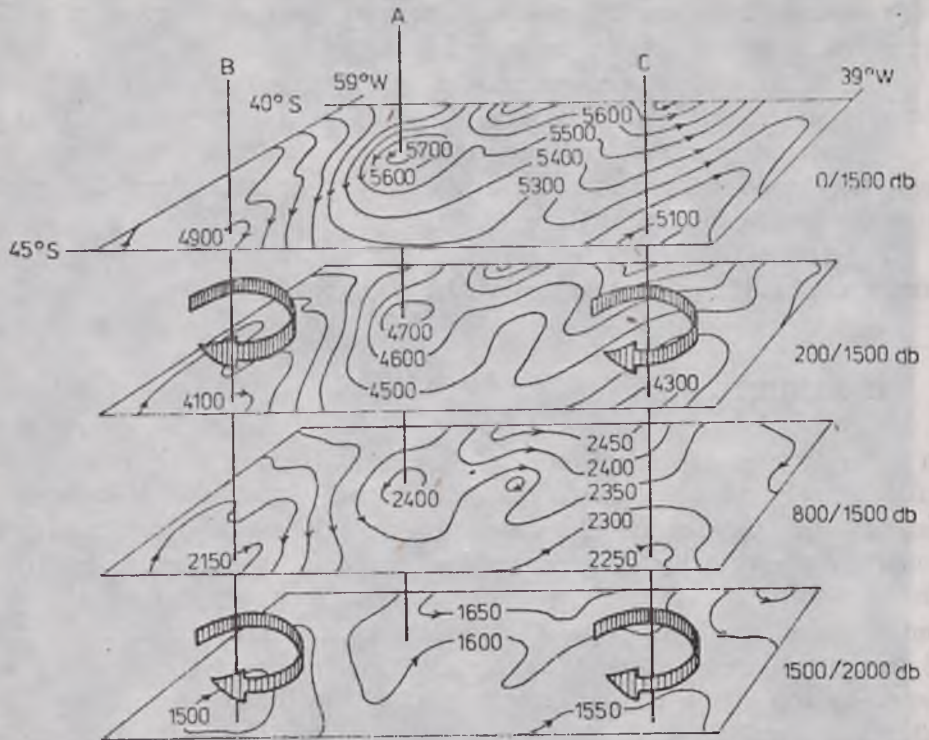

Fig. 2. Geopotential topography of the sea surface, 200 db and 800 db in dynamic millimeters referred to the 1500-db surface and the 1500-db surface referred to 2000 db in the frontal zone of Brazil and Falkland Currents, May 1978.
Rys. 2. Topografia geopotencjalna powierzchni morza, 200 db i 800 db w mm dynamicznych w odniesieniu do powierzchni 1500 db i na poziomie 1500 db w odniesieniu do 2000 db w strefie frontalnej Prądu Brazylijskiego i Falklandzkiego. Maj 1978 r.

with its centre on the B axis. The vertical motion involves waters down to a depth of 1500 db. On the border of these two rings water flows southward with a calculated maximum velocity of about 35 cm s^{-1} in a layer extending down to 100 m from the surface. The anticyclonic ring with its centre lying on the axis gives rise to a meandering movement of the water north-eastwards up to the surface, turning eastward with increasing depth. The disappearance of the northern component with depth is probably due to the action of the wind in the surface layer (52.6 per cent of cases are from the S sector in May 1978), and with the fact that the axis of the South Atlantic Gyre is oblique, deviating southwards [1, 2]. In the south-eastern part of this region, a second local cyclonic ring with its centre on the C axis occurs. These two cyclonic rings (with centre lying on the B and C axes), of about 180 NM in diameter, cause the water to ascend to the surface in the centre, according to the direction of the Coriolis force [5]. This process can be followed in detail on the basis of the spatial distribution of the density which was calculated from the potential temperature and salinity (Fig. 3).

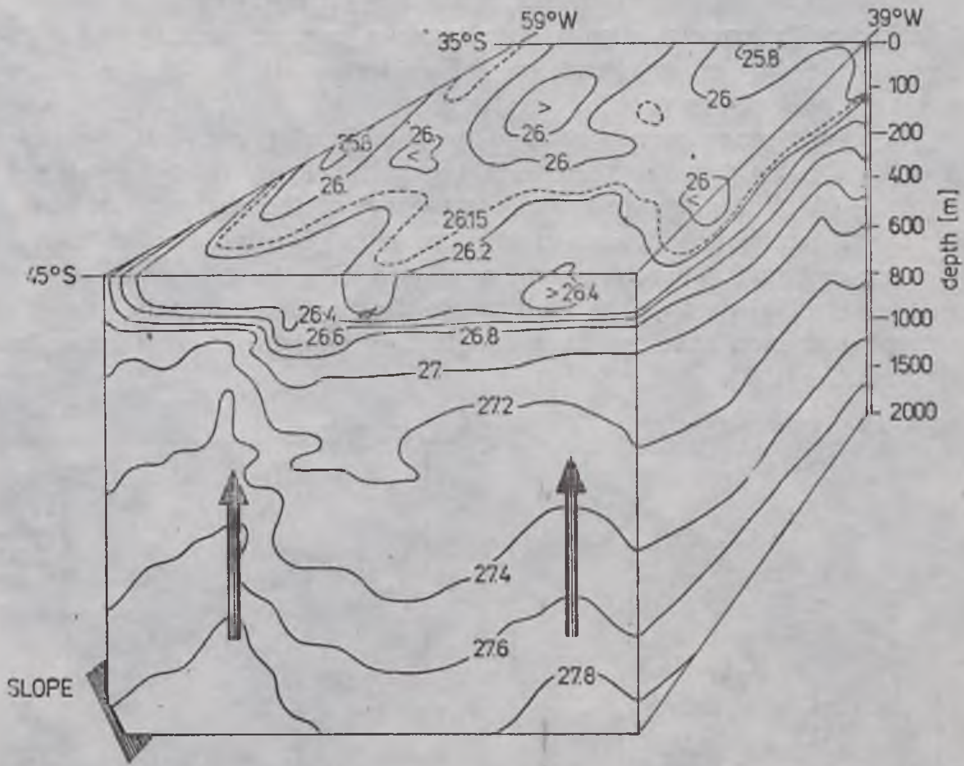

Fig. 3. Three-dimensional density distribution (sigma theta) in the Argentine Basin. May 1978.
Rys. 3. Przestrzenny rozkład gęstości umownej (sigma theta) w Basenie Argentyńskim. Maj 1978 r.

The second feature is the absence of horizontal density gradients in the frontal zone between 40°S and 45°S. This equalization of the densities of surface waters is due to the inflow of cold, low-saline waters of the Falkland Current from the south and warm, more saline Brazil Current waters from the north. Owing to this feature, no horizontal density gradients were noted at the sites of the highest temperature and salinity gradients.

An analysis of the data gave rise to the hypothesis of the distribution of the Brazil and Falkland Currents waters on the surface along $\sigma_\Theta = 26.15$ In the surface layer there was a distinct pycnocline at depths of from 50 to 150 m, lying under the converging layer and corresponding with the first stability maximum. Under this pycnocline, superimposing of the dynamic effects of the Subtropical Convergence, inflow of the Brazil Current waters and occurrence of cyclonic rings appeared in the southern part of this region. As a result, there was an upward deflection and ascending of the isopycnes on the southern wall (marked with arrows), also a simultaneous gradual sinking and diffusion of the vertical gradients on the eastern wall, in the central and northern part of this profile.

Cyclonic rings were observed in the frontal zone of the Brazil and Falkland Currents, their origin can, however, most probably be explained by the phenomenon of the passage of the narrow, fast stream of the Brazil Current, into the wide, slow South Atlantic Current flowing eastward. There are some analogies with the generation of rings in the terminal part of the Gulfstream. So far, however, the causes of this phenomenon have not been satisfactory explained and deserve further studies [1, 3].

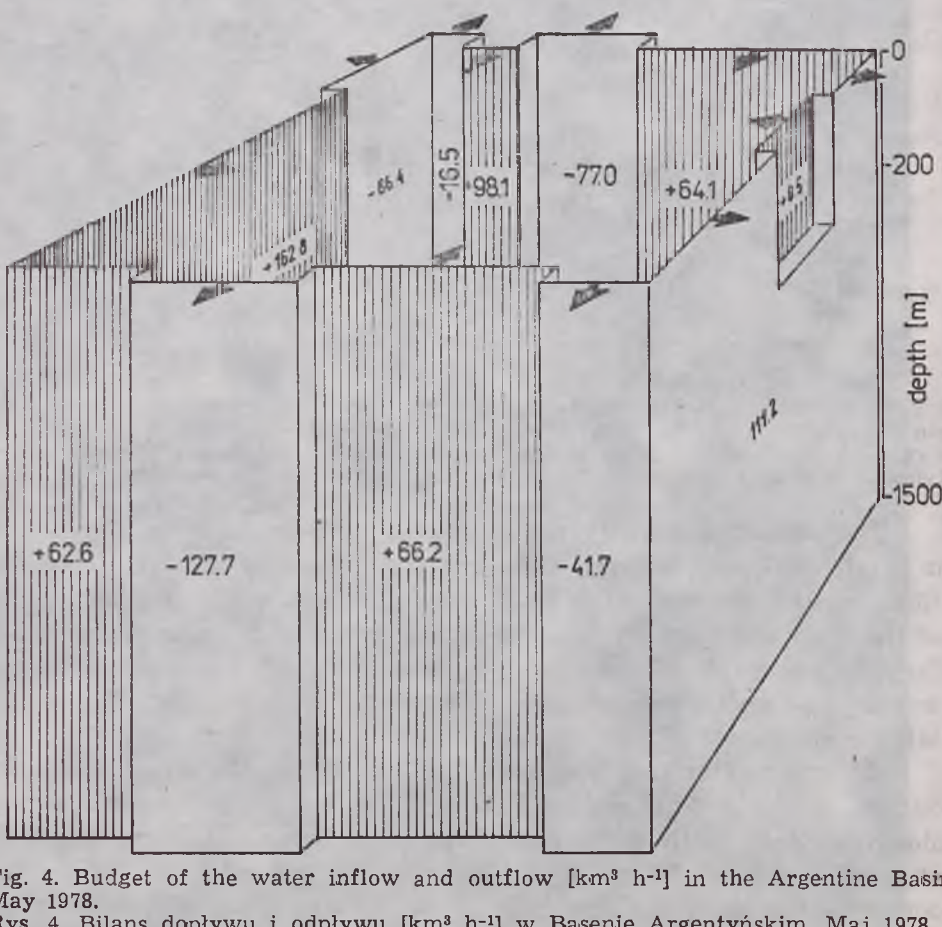

Fig. 4. Budget of the water inflow and outflow [$km^3 h^{-1}$] in the Argentine Basin. May 1978.

Rys. 4. Bilans dopływu i odpływu [$km^3 h^{-1}$] w Basenie Argentyńskim. Maj 1978 r.

The foregoing considerations referred to qualitative phenomena occurring within the prism. However, owing to the fact that intense water movements occur in this region, a quantitative estimation was also made and the movement of water was analysed in the form of a water budget, as illustrated in Fig. 4 and Table. The velocities of geostrophic currents calculated from dynamic heights enable calculations of the flow magnitudes between stations to be carried out and in consequence, the total flow through particular walls of the prism [6].

Wall Ściana	Surface area of the wall Powierzchnia ściany [km²]	Inflow Dopływ [km³ h⁻¹]	Outflow Odpływ [km³ h⁻¹]	Balance Bilans [km³ h⁻¹]
W	2091.00	162.762	—66.410	+96.352
E	1864.05	0.517	—111.238	—110.721
S	1629.75	128.884	—169.408	—40.524
N	1187.80	162.557	—93.447	+69.110
Total balance Bilans sumaryczny		454.720	—440.503	+14.217

Hachures were used to illustrate the flow of waters to the region (positive sign), the remaining fragments of the prism illustrate the outflow of water (negative sign). The numerical values on the walls of the prism denote water volumes flowing in or out of these areas during the period of one hr ($km^3\ h^{-1}$). As in the case of the horizontal distribution of geostrophic currents, the presence of two cyclonic rings was confirmed on the southern wall. However, as the whole phenomenon was not investigated, it is impossible to specify the amount of water taking part in the movement, or the extent and origin of the phenomenon. Nevertheless, it is quite sure that the ring involves waters from the surface down to a depth of at least 1500 m.

The analysis of the balance of water on particular walls of the prism in the layer from 0 to 1500 m of the investigated part of the Argentine Basin shows a preponderance of inflow from the west and north. The outflow takes place on the eastern and southern walls. This conforms with the overall water circulation in this region, as it constitutes the south-western fragment of the anticyclonic South Atlantic Gyre.

The positive total balance between inflow and outflow amounting to + 14,217 km^3 within the whole prism, is probably due to the fact that the fifth plane, providing the base of the prism, was omitted in the calculations. This suggests a steady but slow outflow of water due to the sinking of water masses in the region of the Subtropical Convergence and in waters involved in anticyclonic movement on the A axis in Fig. 2 [5]. Taking into account the total volume of the prism (1,623,000 km^3) and the fact that the foregoing considerations did not take into account the Ekman transport values, the difference between precipitation and evaporation and the reliability of assumptions of the dynamic method, the total time of exchange of water in the prism amounts to about 5 months (assuming that the velocity of the geostrophic currents in the Argentine Basin remains at the value recorded in May 1978).

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PRÓBA OKREŚLENIA DYNAMIKI WÓD W REJONIE ŚCIERANIA SIĘ PRĄDÓW BRAZYLIJSKIEGO I FALKLANDZKIEGO

Streszczenie

Artykuł zawiera opis dynamiki wód strefy frontalnej Prądu Brazylijskiego i Prądu Falklandzkiego (do 2000 m głębokości) wykonany na podstawie badań oceanograficznych przeprowadzonych w Basenie Argentyńskim w maju 1978 r. Stwierdzono obecność dwóch zawirowań cyklonalnych (rys. 2 — osie B i C) oraz jednego wiru antycyklonalnego (rys. 2 — oś A), gdzie ruchem wirowym objęte były wody do głębokości co najmniej 1500 db. Na podstawie prędkości prądów geostroficznych dokonano próby obliczenia bilansu przepływu na poszczególnych ścianach badanego graniastosłupa (rys. 4 i tablica). Na ścianach północnej i zachodniej stwierdzono napływ wody w badany rejon, z kolei odpływ wody miał miejsce na ścianach wschodniej (maksymalna wartość) i południowej (minimalna wartość). Dodatni bilans sumaryczny między dopływem i odpływem (w skali całego graniastosłupa + 14.217 km^3/godz.) sugeruje stałe, aczkolwiek powolne zapadanie wody w rejonie konwergencji subtropikalnej.

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