THE DISTRIBUTION OF WATER MASSES IN THE SOUTH SHETLAND ISLANDS AREA DURING FIBEX

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Abstract: Observations on stratification of temperature, salinity and sound-velocity in the Weddell-Scotia Confluence area were made during the international FIBEX (First International BIOMASS Experiment) multiship echo survey between January 26 and March 1, 1981. The measurements, performed from R.V. WALTHER HERWIG, during the second cruise leg between March 10 and 22, 1981 were done in the area of the South Shetland Islands. By means of a water mass-analysis and geostrophic computations the areas of specific interest to krill biology are related to the sphere of influence of the Bellingshausen Sea, the Scotia Sea and the Weddell Sea, respectively. The temperature measurements during the FIBEX echo survey indicate the complex structure of the Weddell-Scotia Confluence. The interaction of waters from the Scotia Sea and the Weddell Sea leads to a meandering frontal zone. From this meandering current border a patch of "warm" Scotia water was observed to travel into the Weddell Sea. The striking coincidence in the geographical location of a meander east of 50°W with previous observations might be a reference that the bottom topography of the southern Scotia Ridge plays an important role in the formation and maintenance of the Weddell-Scotia Confluence properties. A detailed water mass analysis reveals that the Weddell Sea water effectively influences the Bransfield Strait and the Gerlache Strait. Geostrophic computations corroborate these findings.

1. Introduction

The South Shetland Islands are situated in an area where water masses of Pacific and Weddell Sea origin meet and mix. At the eastern corner of the archipelago in the vicinity of Elephant Island a pronounced current border between both water masses starts its wavy path denoted as Weddell-Scotia Confluence (GORDON, 1967). The general position and the interannual variation of location of this boundary are given by MASLENNIKOV and SOLYANKIN (1979). Based on the hydrographical and the biological materials of expeditions carried out in the sixties and seventies MASLENNIKOV and SOLYANKIN (1980) describe the possible role of water dynamics in the maintenance of krill (*Euphausia superba* DANA) population in the Weddell Sea. According to their findings the Weddell-Scotia Confluence is the northern boundary of the Weddell Sea krill population. Concerning the mode of formation of the vertical homogeneity of the water column in the area of the Weddell-Scotia Confluence, previous authors explain it due to intensive vertical convection during winter (*e.g.* DEACON, 1937; DEACON and MOOREY, 1975). A recent publication, based on historical data, offers an explanation that the hydrographic situation within the Weddell-Scotia Confluence is not merely the consequence of a mixture of the adjacent water masses. Instead, PATTERSON and SIE-

VERS (1980) propose the anomalous "properties of the waters in this area being the result of water mass modifications being imposed upstream or by local processes". Based on the measurements as obtained by R.V. WALTHER HERWIG during FIBEX (First International BIOMASS Experiment) (STEIN, 1981) the observations indicate the separation of Scotia Sea water from the meandering current border. Consequently the deep waters of the Confluence show evidence of mixing with warm Pacific water. Furthermore it was found that the warming of the upper surface layer during the summer months leads to a temporarily "masking" effect.

The present study deals with the measurements, performed from R.V. WALTHER HERWIG between January 26 and March 22, 1981 in the South Shetland Islands area. By means of a water mass analysis and geostrophic computations the areas of specific interest to krill biology are related to the sphere of influence of the Bellingshausen Sea, the Scotia Sea and the Weddell Sea, respectively.

2. The Data

Based on the West German FIBEX CTD data a basic T, S diagram for the South Shetland Islands area was plotted (Figs. 3a and 4a). The temperature distribution between 48°W and 56°W (Fig. 1) was constructed from XBT and CTD data performed from R.V. WALTHER HERWIG. For geostrophic computations the CTD data were used to calculate relative speeds (Fig. 5).

3. Horizontal Distribution of Temperature

At the northern break of the southern Scotia Ridge the meandering temperature contour lines indicate the position of the Weddell-Scotia Confluence (Fig. 1). This is in close correlation with FOSTER (1975) who emphasized "that the Scotia Ridge effec-

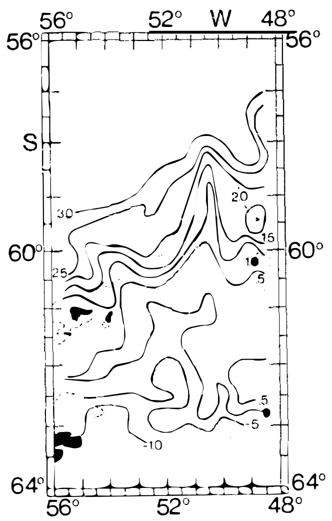

Fig. 1. Sea surface temperature (°C) in the survey area of R.V. WALTHER HERWIG (January 26 to February 28, 1981); depth contours: dotted line 1000 fathoms, dashed line 100 fathoms.

tively separates the water of the circumpolar current in the north from the Weddell Sea water in the south". East 50°W the Scotia Sea water extends to the southeast. South of this meander a patch of rather warm water was observed in the vicinity of the Confluence. To the west a tongue of cold water is directed northward. Whereas the former may indicate Scotia water traveling south, the latter might be a hint that Weddell water travels to the north. PATTERSON and SIEVERS (1980) emphasized that interactions with the bottom topography of the southern Scotia Ridge play an important role in the formation and maintenance of the Weddell-Scotia Confluence (WSC) properties. The striking coincidence in the geographical location of the meander east of 50°W with previous observations might be a reference to such interaction. Based on the ELTANIN data PATTERSON and SIEVERS (1980) report a meander in this area originating from the Scotia Sea. A similar observation was made during FDRAKE-75 (GORDON *et al.*, 1977).

4. Vertical Distribution of Temperature and Sound Velocity

The vertical stratification of temperature (T) and sound velocity (c) in the vicinity of the Antarctic Peninsula is given in Fig. 2. The observations performed on March 11 and 12, 1981 from R.V. WALTHER HERWIG delineate different water masses. Above the seasonal thermocline which ranges around 50 m depth in the northern portion of the section, the influence of the Pacific water may be traced between stations 220 and 224. Far more south the mixing of the near surface layer increases. This might also be detected by the vertical distribution of sound velocity. Within this water mass, according to SIEVERS and EMERY (1978) the "Continental Slope Water", the sound velocity is about 10 m/s lower than in the Pacific water.

The dotted line in Fig. 2 represents the depth of the temperature minimum layer. Below the Bellingshausen Sea Winter Water, core temperature less than -1.5°C, the transition to the Warm Deep Water is visible.

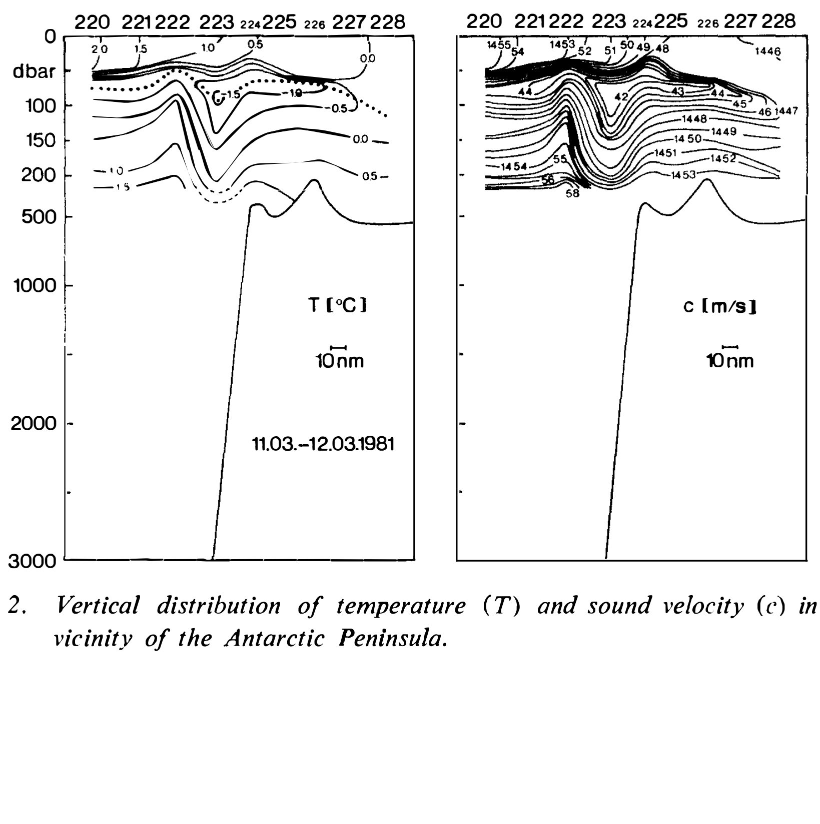

Fig. 2. Vertical distribution of temperature (T) and sound velocity (c) in the vicinity of the Antarctic Peninsula.

5. T, S Analysis

The distribution of temperature and salinity in the T, S diagrams varies regionally. Thus, it seemed worthwhile to identify different regions of water mass distributions. Part a of Figs. 3 and 4 outlines the shapes of T, S curves in these different regions.

5.1. FIBEX echo survey area

For a T, S analysis the "FRG box" was devided into three parts:

56°S–60°S area north of the WSC, 62°S–64°S area south of the WSC,
60°S–62°S area of the WSC.

In the northern part of the area (Fig. 3b) the seasonal warmed surface water of the Scotia Sea was found (T: 3.5–4.0°C; S: 33.7–33.8‰). Although the Winter Water layer in this region is mostly influenced by the water masses of the Bellingshausen Sea there are some signals of the Weddell Sea. Whereas the T, S characteristics of the former water mass are T: 0.5°C; S: 34.0‰ the Winter Water of Weddell origin is characterized by T: 0.5°C; S: 34.5–34.6‰. The Warm Deep Water was found within the range of T: 1.5–2.2°C; S: 34.6–34.78‰.

South of the Weddell-Scotia Confluence (Fig. 3c) the influence of the ice becomes

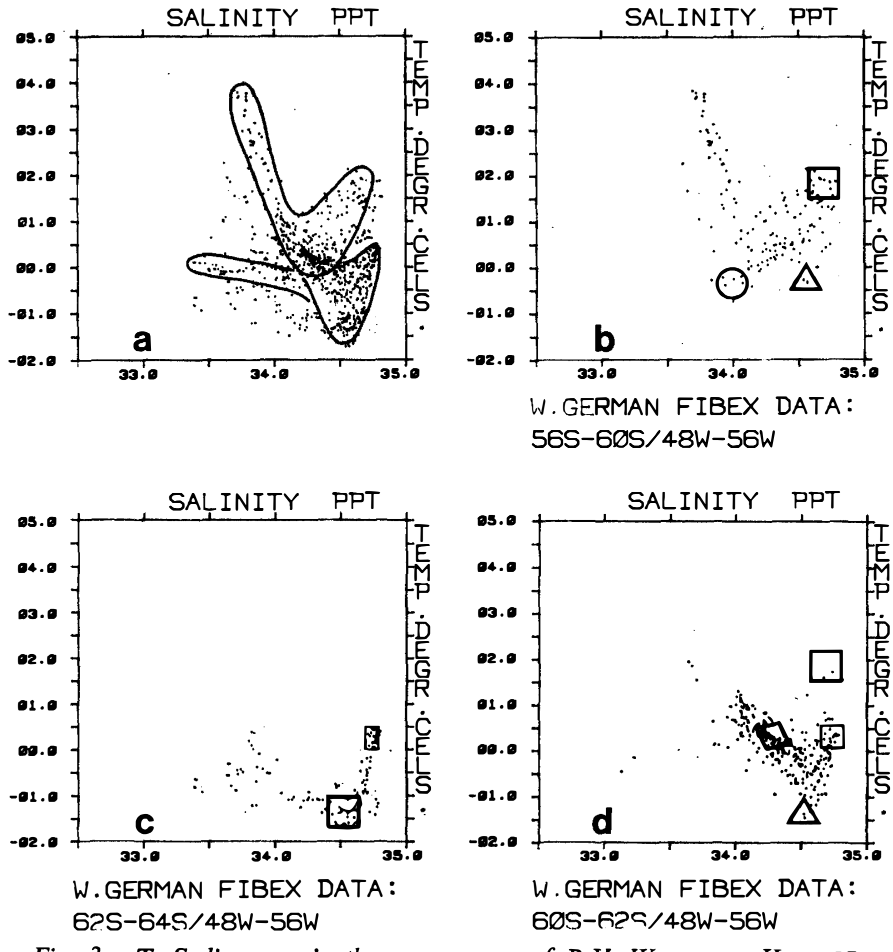

Fig. 3. T, S diagrams in the survey area of R.V. WALTHER HERWIG.

apparent. Near the ice border the surface water has a salinity of less than 33.5‰, the temperature ranges between −0.5°C and −1.0°C. Far more distant from the ice the T, S values are between 0.5°C and 0°C, 33.8‰ and 33.9‰, respectively. In this area the Winter Water layer is as cold as −1.75°C, with a salinity ranging from 34.4‰ to 34.65‰. The Warm Deep Water (T: 0.5–0°C; S: 34.7–34.8‰) is about 2°C colder than north of the Confluence. Between 60°S and 62°S (Fig. 3d) except the

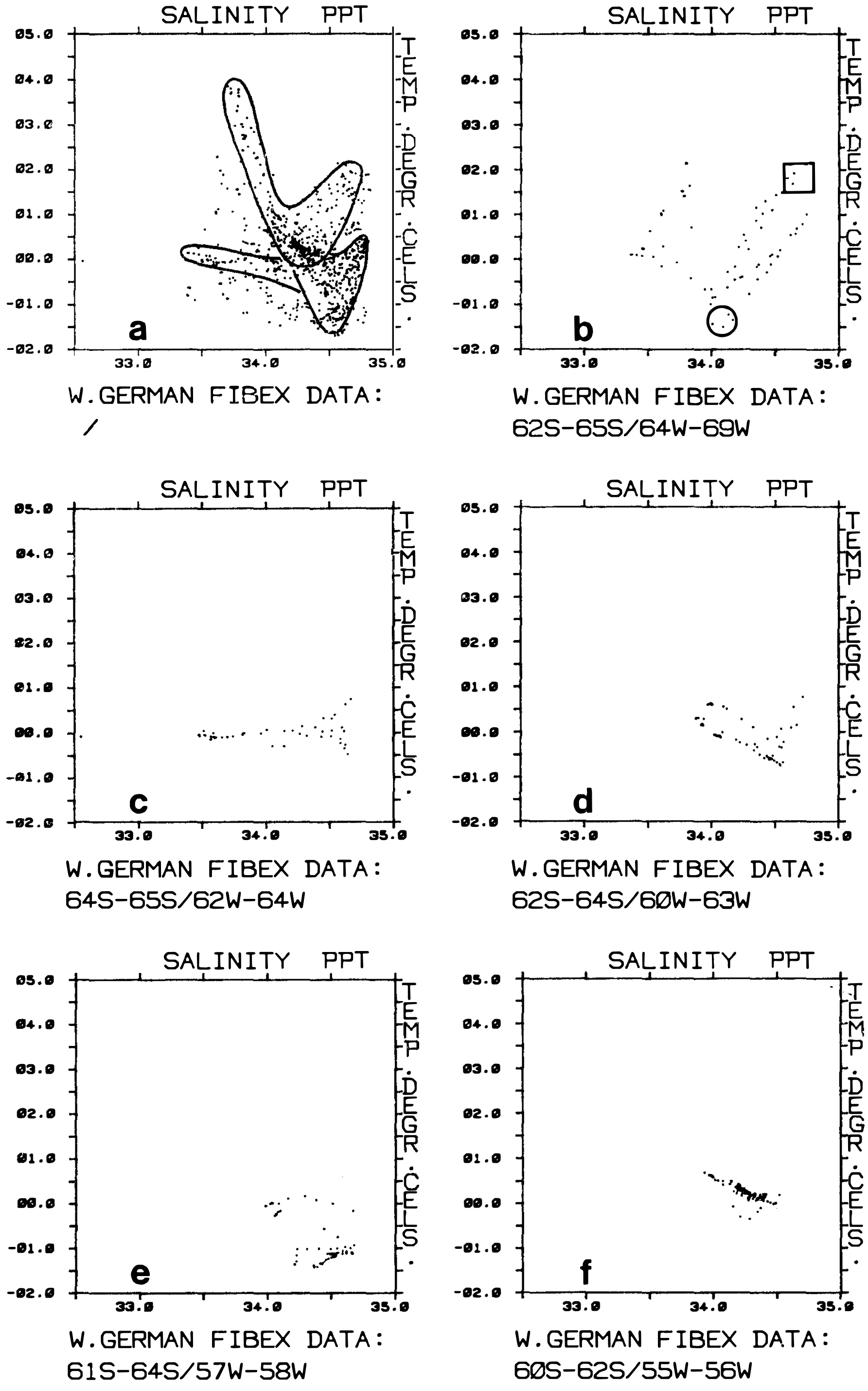

Fig. 4. T, S diagrams in the South Shetland Islands area.

Bellingshausen Sea water all water masses mentioned above compose the thermohaline structure of the Weddell-Scotia Confluence region. The temperature of the surface water amounts 1.5°C to 2°C, the salinity ranges from 33.6‰ to 33.7‰. Around Elephant Island a profound mixing of the near surface water masses is observed.

5.2. Area of the second cruise leg

According to the sequence of biological/oceanographic stations the area of the second cruise leg is divided into the following regions:

Northeastern Bellingshausen Sea, Gerlache Strait, western Bransfield Strait, eastern Bransfield Strait, Elephant Island.

The T, S diagram of the northeastern Bellingshausen Sea (Fig. 4b) delineates the warmed surface water, Winter Water and Warm Deep Water. In the Drake Passage the surface values are 1.5°C to 2.0°C and 33.7‰ to 33.8‰, respectively. In the vicinity of the shelf of the Antarctic Peninsula the surface salinity and surface temperature decrease to values below 33.5‰ and 0°C. The T, S values of the remnant of winter convection, the Winter Water layer, range between T: −1.0°C to −1.5°C and S: 34.0‰ to 34.2‰. The square in Fig. 4b marks the Warm Deep Water.

The T, S characteristics of the Gerlache Strait (Fig. 4c) indicate the influence of Weddell Sea water. Comparing Fig. 4c with Fig. 3c one can easily detect that the right part of the T, S diagram (Gerlache Strait) ranges in the mixing-line between Weddell Sea water and Warm Deep Water.

Also very strongly mixed is the western part of the Bransfield Strait (Fig. 4d). Again the influence of the Weddell Sea becomes apparent. The Winter Water layer in the eastern part of the Bransfield Strait is dominated by the Weddell Sea (Fig. 4e), whereas around Elephant Island (Fig. 4f) a profound mixing of the water column is visible.

6. Geostrophic Computations

The determination of the geostrophic current field in the area of the South Shetland Islands is a rather difficult task. According to CLOWES (1934) "water from the Bellingshausen Sea flows in a north-easterly direction at the south-western end of the strait, is diverted by the shelves of the islands of Brabant, Low and Smith, and enters the Bransfield Strait between Smith and Low Islands. Another inflow is the relatively deep channel between Smith and Snow Islands. This water continues up the strait in a north-easterly direction, after having passed north or south of Deception Island. The north-easterly current along the southern coast of the South Shetland Islands is relatively strong. Part of the water which has passed Deception Island makes a characteristic bend to the south-east and sometimes reaches more than half-way across the strait before it turns again to the north-west to join the current along the South Shetland Islands. At the eastern end of the strait the influence of a current from the Weddell Sea is apparent".

It is obvious that a current field as complex as it appears in the area of the Bransfield Strait cannot be described sufficiently by two sections alone (Fig. 5) which cross the western entrance and the eastern exit of the strait. This task can, however, be full-

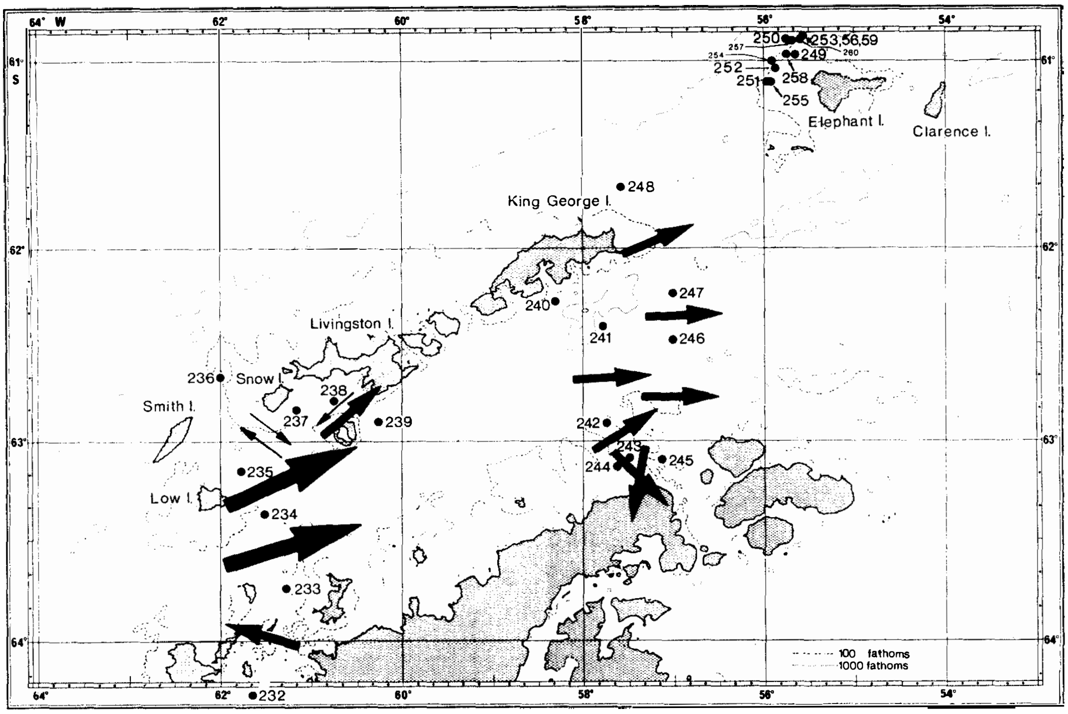

Fig. 5. Location of biological/oceanographic stations during cruise leg 2 (arrows indicate the direction of the relative geostrophic current, small sized arrows: max (v_{rel})<1 cm/s; medium sized arrows: 1 cm/s≤max (v_{rel})<5 cm/s; large sized arrows: 5 cm/s≤max (v_{rel})<10 cm/s).

filled by means of the FIBEX oceanographic data set. This data set enables a coverage of the South Shetland Islands area which is sufficient to give a detailed description of the flow of water masses inside the strait and off the islands.

However, from the section lines the following information can be taken. The relative geostrophic currents as computed between the individual pairs of stations vary considerably. The strong inflow from the west (Fig. 5) is accompanied by a flow out of the strait which takes place in the southwestern part between stations 232 and 233. A very uniform flow out of the Bransfield Strait was found between stations 241 and 248 with the exception of stations 243, 244 and 245. Between these stations a very weak geostrophic current was observed. The relative currents are directed shoreward indicating a southwesterly current along the Antarctic Peninsula.

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