# SOME CHARACTERISTICS OF SUMMER OCEAN STRUCTURE OFF THE QUEEN MAUD LAND, ANTARCTICA

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***Abstract*:** The hydrographic data of FUJI (Japanese Antarctic Research Expedition: JARE) obtained in the austral summers of 1966–1969 and 1973–1975 in a sector of 60°–70°S and 30°W–15°E, where the Weddell polynya appeared during the winters of 1973–1977, are examined for finding out the influence of a winter polynya on summer ocean structure, in comparison with the cruise-12 data of the ARA ISLAS ORCADAS obtained in the same sector in the austral summer of 1977.

The vertical profiles of temperature, salinity and sigma-*t* at station 75–7 (67°27′S, 2°04′E) on February 26, 1975, for the JARE-16 show anomalous characteristics featuring the absence of water below 0°C, both the weak minimum and the weak maximum temperature profile, a high-salinity water at the depth where the temperature is minimum, and a shallow picnocline. These features, which reveal the upward movement of saline water, are different from the anomalous features at station 115 of the cruise of the ISLAS ORCADAS, where the sinking of the cooled surface water occurred, as explained by GORDON (J. Phys. Oceanogr., **8**, 600, 1978) and KILLWORTH (J. Phys. Oceanogr., **9**, 531, 1979).

The same features as the profiles at stations 75–7 and 115 are found at stations 118 and 125 respectively in the ISLAS ORCADAS data. These four stations were located near the margin of the polynya in the preceding winter, and both types of anomalous features reveal that strong convection, which occurred locally in the polynya area in the preceding winter, influences summer ocean structure.

## 1. Introduction

A large polynya (or a weak ice zone) was observed in the extent of winter sea-ice off the Queen Maud Land, Antarctica, by Nimbus-5 ESMR (Ellectrically Scanning Microwave Radiometer) in the winters of 1973–1977 (CARSEY, 1980; ZWALLY *et al.*, 1981). It was named the Weddell polynya, because it was found in almost the same area in the Weddell gyre, though the size and shape of the polynya varied with the year. CARSEY (1980) noted that the polynya shifted westward year by year at the rate of about 1 cm/s.

Hydrographic observations were carried out by the ARA ISLAS ORCADAS in this polynya area in her cruise-12 in the austral summer of the 1977 (HUBER *et al.*, 1981). GORDON (1978) found a chimney-like water column of 14 km in radius at station 115 to the west of the Maud Rise. A special survey made around the station showed that the water was cold, low in salinity, high in oxigen, and extended at least to a depth of 4000 m, with an associated cyclonic eddy of about 0.5 m/s in surface velocity.

KILLWORTH (1979) explained that the chimney is a surface-driven phenomenon caused by surface cooling in the preceding winter.

Hydrographic observations were also carried out in this area by the JARE (Japanese Antarctic Research Expedition) aboard the FUJI en route from Syowa Station during the austral summers of 1966–1969 and 1973–1975. In the present study the FUJI data are examined for finding out the influence of the Weddell polynya on summer ocean structure in comparison with the ISLAS ORCADAS cruise-12 data.

## 2. Data Sets

A sector of 60°–70°S and 30°W–15°E, where the Weddell polynya was observed in the winter ESMR imageries, is subjected to an examination on hydrographic features in summer. A total of 20 hydrographic stations were present in the sector in the seven cruises of the JARE-7 ~-10 from 1966 to 1969 and the JARE-14 ~-16 from 1973 to 1975. At these stations serial observations were conducted using Nansen bottles with reversing thermometers. Sources of the hydrographic data are listed as separate references at the end of the present paper.

A set of the data obtained at 41 CTD stations in the same sector by the ISLAS ORCADAS in her cruise-12 in January and February 1977, are also used in the present study.

Tracks of these cruises are illustrated in Fig. 1 by solid lines for the FUJI and a

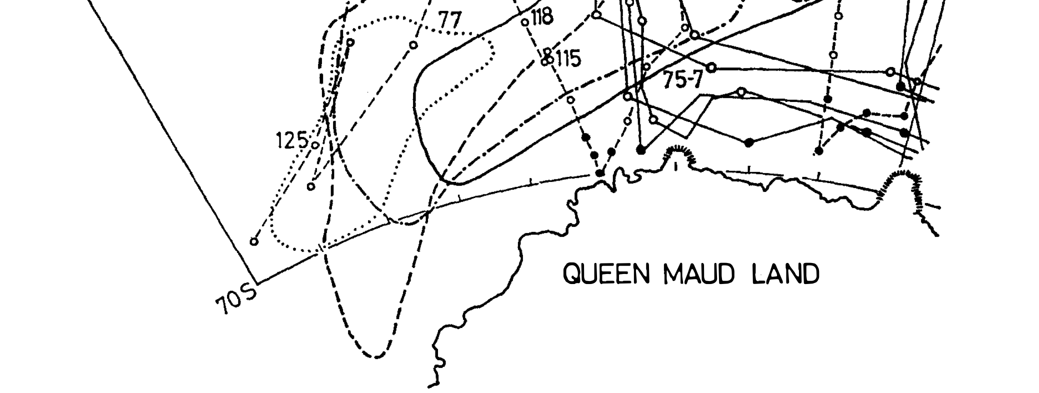


*Fig. 1. Tracks of the JARE FUJI (solid lines) and the ARA ISLAS ORCADAS (dashed line) with hydrographic stations (solid circles for coastal stations; open circles for other stations). The shape and location of the Weddell polynya at the end of each austral winter during 1973–1977.*

dashed line for the ISLAS ORCADAS. The stations are marked by open circles except those near the coast of Antarctica which are marked by solid circles.

The size, shape and location of the Weddell polynya are also drawn in the figure as the maximum extent at each end of the austral winters of 1973–1977. Numerals attached to both polynyas and tracks show the years subtracted by 1900. It follows from the figure that the crossing of the polynya area of the preceding winter occurred in cruise-75 of the FUJI and cruise-12 of the ISLAS ORCADAS. Numerals on four stations of these cruises indicate the station numbers where anomalous features were observed.

## 3. Results and Discussions

Vertical profiles of temperature, salinity and sigma-*t* at all stations in Fig. 1 are summarized in Figs. 2–4 as composite drawings down to the depth of 5000 m. Data at the stations marked by open circles in Fig. 1 are shown in Fig. 2 for 15 stations of the FUJI cruises, and in Fig. 3 for 32 stations of the ISLAS ORCADAS cruise-12. Data at the coastal stations marked by solid circles in Fig. 1 are shown in Fig. 4 by open circles for 5 stations of the FUJI cruises and by dots for 9 stations of the ISLAS ORCADAS cruise.

General hydrographic features in summer in the sector off the Queen Maud Land represented in these figures are described as follows:

a) Under a warmed surface water in summer, a cold low-salinity water exists

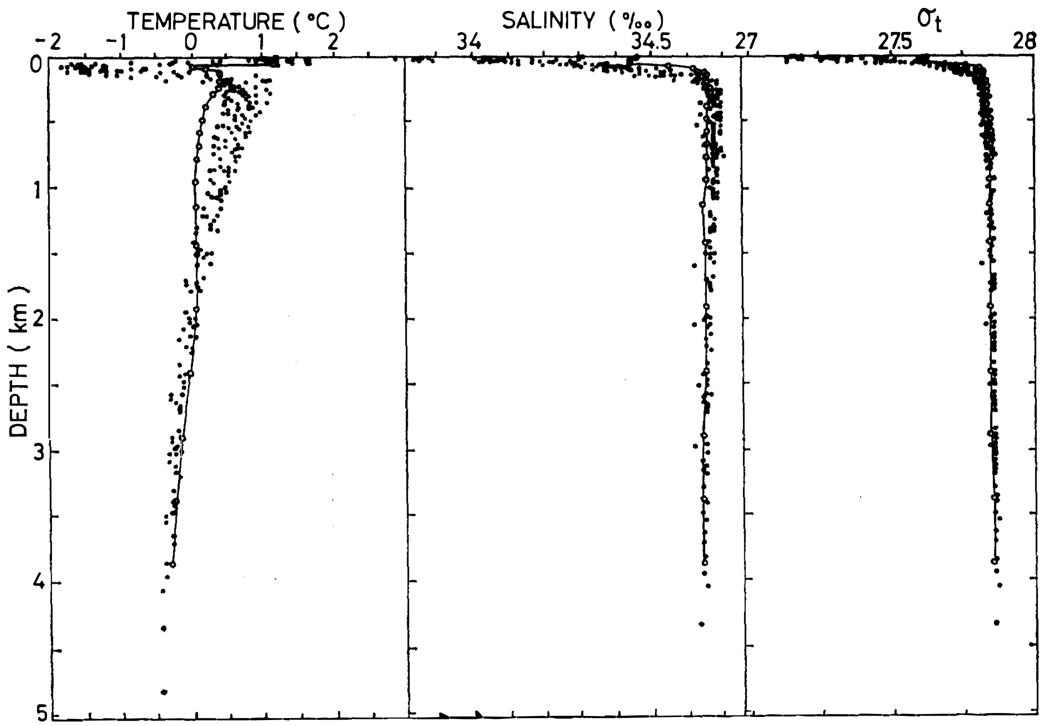


*Fig. 2. Vertical profiles of temperature, salinity and sigma-t at 15 stations marked by open circles from the FUJI cruises in Fig. 1. The solid line with open circles shows the data at station 75–7.*

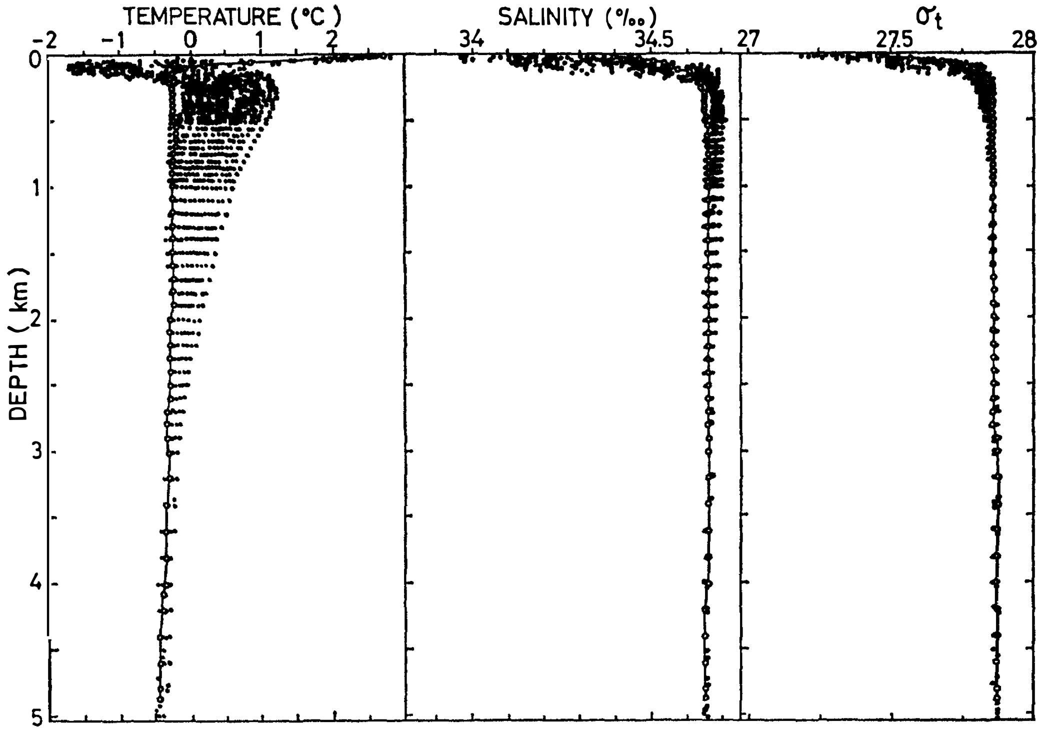


*Fig. 3. Vertical profiles of temperature, salinity and sigma-t at 32 stations marked by open circles from the ARA ISLAS ORCADAS cruise in Fig. 1. The solid line with open circles shows the data at station 115.*

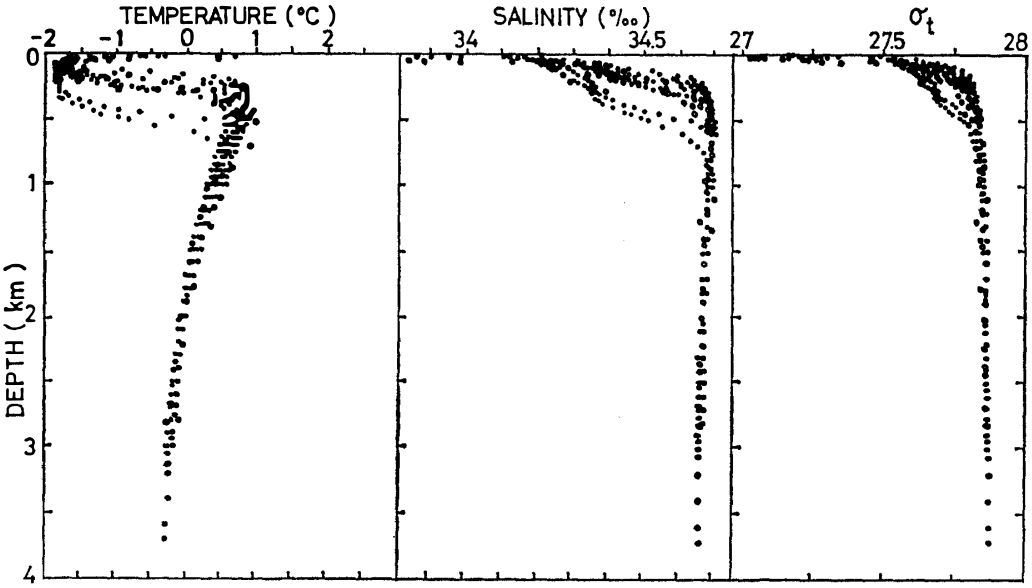


*Fig. 4. Vertical profiles of temperature, salinity and sigma-t at the coastal stations marked by solid circles in Fig. 1 from the cruises of the FUJI (5 stations; open circles) and the ISLAS ORCADAS (9 stations; dots).*

above the depths of 100–150 m. The minimum temperature below 0°C is recognized in this water between 50–100 m in depth. The thickness of the water increases in the coastal area, as is shown in Fig. 4.

b) Under the cold low-salinity water a warm saline water is observed at the depths of 100–1000 m. The maximum temperature of 0°C to +1.2°C appears in this water between 100 and 150 m in depth.

c) A deep water of 34.6–34.7‰ in salinity and slightly below 0°C lies under the depths of 2000 m.

Anomalous features were found on the profiles at station 75–7 (67°27′S, 2°04′E) of the JARE-16 on February 26, 1975. The profiles of temperature, salinity and sigma-*t* at station 75–7 are illustrated by a solid line with open circles in each profile of Fig. 2, and are characterized as follows:

a) Under a warmed surface water in summer, the absence of water below 0°C is observed. The minimum temperature on the profile is +0.02°C at the depth of 69 m, where the salinity of water is 34.548‰, that is the highest among values in the surrounding water at the same depth.

b) A warm saline water found in the general feature is also absent at this station. A cold and relatively low-salinity water lies between 100 and 1500 m in depth, as is clearly shown in Fig. 2. The maximum temperature in this water is 0.42°C at the depth of 139 m with the salinity of 34.661‰.

These anomalous features at station 75–7 are different from the features at station 115 of the ISLAS ORCADAS cruise, where a chimney-like water column was observed by GORDON (1978). The profiles of temperature, salinity and sigma-*t* at station 115 are also shown in Fig. 3 by a solid line with open circles in each figure.

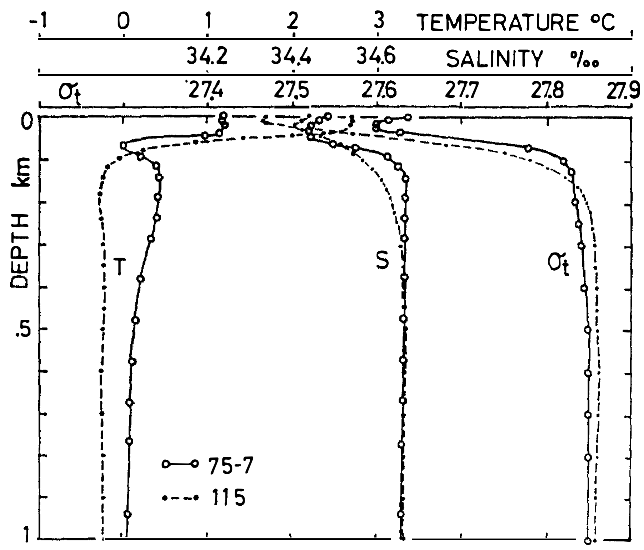


*Fig. 5. A comparison of profiles of vertical temperature, salinity and sigma-t at station 75–7 of the FUJI and station 115 of the ISLAS ORCADAS.*

The profiles above the depth of 1000 m at both stations 75–7 and 115 are compared with each other in Fig. 5. A remarkable difference is found in the layer between 100 and 200 m in depth. In contrast to the cold low-salinity water at station 115 explained by GORDON (1978) and KILLWORTH (1979) as taking place as a result of the sinking of surface water cooled in winter, the presence of a saline and relatively warm water, though colder than the normal warm water, at station 75–7 results from the

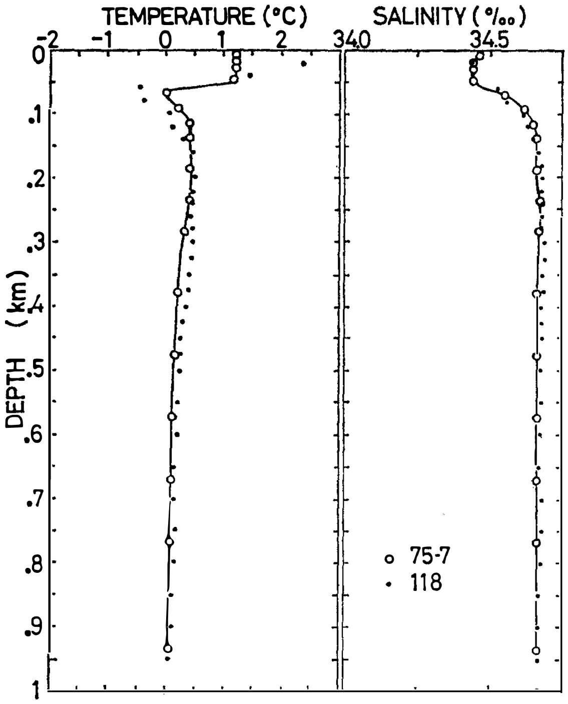


*Fig. 6. A comparison of profiles of vertical temperature and salinity at station 75–7 of the* FUJI *(open circles) and station 118 of the* ISALS ORCADAS *(dots).*

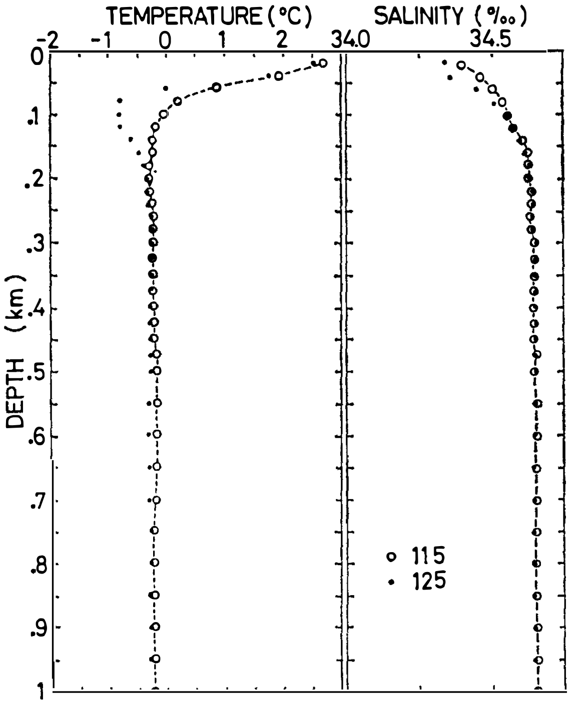


*Fig. 7. A comparison of profiles of vertical temperature and salinity at station 115 (open circles) and station 125 (dots) of the* ISLAS ORCADAS.

upward movement of the deeper saline water. This explanation agrees with the result of the upward shift of a picnocline in the sigma-$t$ profile, as is shown in Figs. 2 and 5.

The same features as the profiles at stations 75–7 of the FUJI and 115 of the ISLAS ORCADAS are found in the set of data from cruise-12 of the ISLAS ORCADAS. Figure 6 shows the profiles of temperature and salinity at stations 75–7 of the FUJI and 118 of the ISLAS ORCADAS. Similarity is found between these profiles concerning features

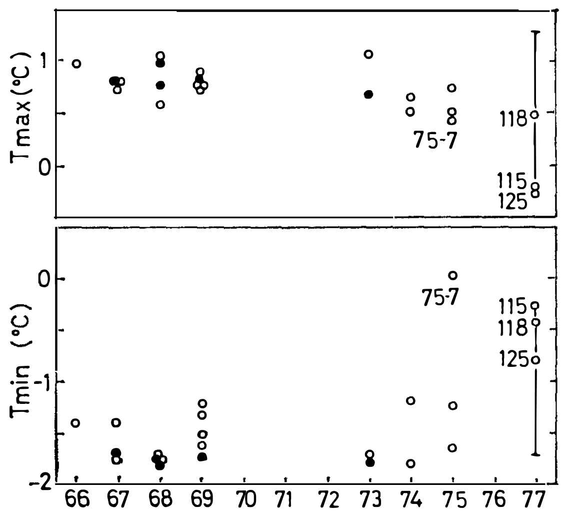


*Fig. 8. Interannual variations in maximum and minimum of temperature at all stations of the* FUJI *cruises. The warmed surface water in summer is excluded in determining the maximum temperature. Data in 1977 are from the* ISLAS ORCADAS *cruise-12. The solid circles show the data of coastal stations.*

of the weak minimum and the weak maximum temperature profile, higher surface salinity than in the surroundings and high-salinity water in the layer between 70 and 200 m in depth. Figure 7 shows similarity between stations 115 and 125 of cruise-12 of the ISLAS ORCADAS. These four stations were located near the margin of the polynya area in the preceding winter, as shown in Fig. 1. The two types of anomalous features-imply that strong convection occurred locally in the wintertime polynya area and the convection affected the summer ocean structure.

Figure 8 shows interannual variations in maximum and minimum in the temperature profile at all stations of the FUJI cruises. In determining the maximum temperatures the warmed surface water in summer is excluded. Data in 1977 are from the ISLAS ORCADAS cruise-12. Four stations with anomalous features described above are shown with the station numbers.

The minimum temperature at station 75–7 is remarkably high, while the maximum temperature at stations 125 and 115 are extremely low. These anomalous features in the figure are limited to the case of both 1975 and 1977, when a large Weddell polynya was observed in the preceding winter. As the anomalous features are not found in the data obtained in the latter half of the 1960's, there is no proof of existence of large polynyas in this period.

The Weddell polynya has disappeared since 1978 from the satellite imageries. Hydrographic observations have not been conducted in this polynya area by the JARE FUJI since 1976, because the route of the FUJI starting at Syowa Station lay east of the polynya area. It is hoped that further observations be conducted in this area by the new icebreaker SHIRASE to increase knowledge of the relationship between the winter polynya and the summer ocean structure.

## Acknowledgments

The authors wish to thank the editor and referees for their helpful suggestions and comments on the earlier version of the manuscript.

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*(Received April 23, 1983; Revised manuscript received July 19, 1983)*