A Report on the Oceanographical Observations in the Antarctic Ocean Carried Out on Board the Japanese Whaling Fleet During the Years 1946 to 1952

By

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1. Summary

In the present treatise the chief characteristics of the oceanographical conditions of the Antarctic Ocean are founded on the observations taken on board the Japanese whaling fleet during the years 1946 to 1952. Among many interesting facts found by the Japanese fleet, we may mention these significant points.

1) In the Antarctic Ocean, the temperature and chlorinity graph of the sea surface increases in the shape of a parabola as the distance from the pack-ice line increase.

2) Ocean currents computed from dynamic calculation near the Scott Island in 1949 show eastward flow to the north of 67° S, and southward flow along the 180° line to the south of 67° S.

3) The insignificance of the Antarctic circumpolar water is due to bottom topography and to small clockwise circulations.

4) The boundary of two currents is a good whaling ground, even in the Antarctic Ocean, and in the homogeneous area good whaling is not expected.

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2. Introduction

The Antarctic whaling industry of Japan, which is one of the most important marine product industries in this country, was completely destroyed by World War II. Many whaling factory ships and catcher boats were sunk during the war. But a serious shortage of food on account of exhaustion and the loss of territory by the defeat soon forced Japan to reconstruct the Antarctic whaling industry in as short a period as possible. Due to the united efforts of the government and the people, the labor of the reconstruction bore its fruits soon, and by the fall of 1946, Japan sent her first post-war whaling expedition to the Antarctic Ocean.

Opportunity for two observers of the Central Meteorological Observatory to join to this cruise was afforded and since then it has become a usual practice that on every cruise C.M.O. observers accompany the expedition.

Of course, even in the pre-war cruises, simple surface observations were performed by deck officers on board the fleet, but after the war it was the first time that experts of oceanography and meteorology were dispatched to the Antarctic Ocean with the whaling fleet. Since then the study of the physical and chemical conditions of the Antarctic Ocean, together with the meteorological observations and investigations, has been continued to the present. During these years, oceanographical observations were taken with the following general objectives, namely:

1) To make temperature, chlorinity, dissolved oxygen and nutrient salts measurements on the surface and to a depth of about 400m, from which general oceanographical conditions could be concluded.

2) To ascertain the horizontal and vertical distribution of plankton in those waters.

The present paper is a collected report on the studies made of the Antarctic Ocean, based on the data obtained with our whaling fleet.

3. Outline of the cruises and operations

(1) General aspect

Our oceanographical observations were usually taken from on board the whaling factory ships which are equipped with hand-operated winches. Our fleet departs from Japan in late fall and returns in spring, therefore the period of observation in the Antarctic Ocean is the summer of the Southern Hemisphere. Surface observation en-route to and from the Antarctic Ocean were also performed. Cruise number, ships, names, and elements of the observations are tabulated in the following table:
<table>
<thead>
<tr>
<th>Date</th>
<th>Location</th>
<th>Remarks</th>
<th>Element of Observations</th>
<th>Cruise Name</th>
<th>Number of Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>1911-11-16</td>
<td>105°E - 106°W</td>
<td>§ S.S.</td>
<td>Neptune</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>1911-11-19</td>
<td>105°E - 110°W</td>
<td>§ S.S.</td>
<td>Neptune</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>1911-11-20</td>
<td>105°E - 112°W</td>
<td>§ S.S.</td>
<td>Neptune</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>1911-11-21</td>
<td>105°E - 112°W</td>
<td>§ S.S.</td>
<td>Neptune</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>1911-11-22</td>
<td>105°E - 112°W</td>
<td>§ S.S.</td>
<td>Neptune</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>1911-11-23</td>
<td>105°E - 112°W</td>
<td>§ S.S.</td>
<td>Neptune</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>1911-11-24</td>
<td>105°E - 112°W</td>
<td>§ S.S.</td>
<td>Neptune</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td>1911-11-25</td>
<td>105°E - 112°W</td>
<td>§ S.S.</td>
<td>Neptune</td>
<td>14</td>
<td></td>
</tr>
</tbody>
</table>

Table 1. General scope of observations on board Japanese whaling ships.
(2) **Description of the region**

As the Antarctic whaling ground extends from 100° E to 160° W and from ca. 60° S to 75° S, our observation is limited to those regions. The observation area somewhat differs every year according to the changes of good whaling grounds.

(3) **Description of the stations**

Stations were not scheduled in advance. Observations were carried out at any positions where the factory ship stopped for a considerable length of time for whaling operations. Distribution of stations is therefore not regular as shown in figure 1. Stations of the various years are indicated by differentiated symbols.

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**Fig. 1.** Distribution of oceanographic stations in the Antarctic Ocean occupied by the Japanese Antarctic Whaling Fleet.

4. **Experimental methods**

(1) **Collection of samples**

Surface samples were obtained at a constant time interval whether the ship was moving or not. They were picked up from the moving ship by means
of a bucket lowered over the side. Sub-surface samples were collected by means of reversing bottles of the Nansen type. The sampling depth varied according to the wire used, but was limited to approximately 800 meters. Sampling operations were not carried on during rough weather.

(2) Determination of depth

The depth of each observation was determined from the reading of the gauge which measured the length of wire dropped, and then correcting this length for wire angle. Unprotected thermometers, which indicate water pressure, were also used to measure the depth obtained.

(3) Determination of temperature

The water temperature at the various depths were determined by means of reversing thermometers in Nansen bottles. The thermometers were of Japanese manufacture and could be read with an error of less than 0.02°C.

(4) Determination of chlorinity

The chlorinities were determined by titration on board. Standard sea water approved by C.M.O. was used. The probable error of the chlorinity determination does not exceed 0.01%o. Method of determination of other chemical components will be shown in later paragraphs.

5. Discussion of results of observations

(1) Surface temperature and chlorinity

Surface temperature and chlorinity were measured about 4500, and 500 times respectively during the years 1946 to 1952. On the whaling grounds surface temperature was generally below 0.0°C, having a maximum of 2.8°C and a minimum of −1.8°C. The mean surface chlorinity was somewhat saline compared with that of the Central Oyashio Water. The maximum was 18.94%o, and the minimum was 17.91%o (SUGIURA, J. 1950). Mean seasonal value of the surface water temperature for each 2.5° × 5° section in the Antarctic Ocean, based on the data obtained in the 1946–1951 seasons, are given in figure 2. In making this figure, we assumed that the change of surface temperature, month by month, is negligibly small, so this chart is of a climatological nature.

(2) Variation of oceanographical condition with time

i) Diurnal variation of surface temperature at one station

As the whaling fleet migrates frequently to and fro in the Antarctic Ocean, so the continuous observation at the same point for a considerable period, say, for a day was very infrequent. Therefore characteristics of diurnal variation
in the open Antarctic Ocean has not yet been clarified. However, scarce observation indicates that the diurnal variation is of rather small range. The following example is a sample observation showing how the range is of small magnitude. (SUGIURA, J. 1950)

![Climatological mean sea surface temperatures](image)

**Fig. 2.** Climatological mean sea surface temperatures (°C) for each 2.5° × 5° square in the Antarctic Ocean during the whaling seasons of the years 1946-'51. (Upper figures are mean sea surface temperatures obtained mainly by bucket sampling. Lower figures are number of observations in each unit area.)

**Position 63° 54’ S, 158° 30’ E**

<table>
<thead>
<tr>
<th>Local time</th>
<th>22h30m</th>
<th>00h30m</th>
<th>07h30m</th>
<th>10h30m</th>
<th>12h30m</th>
<th>16h30m</th>
<th>19h30m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date Dec. '47</td>
<td>28th</td>
<td>29th</td>
<td>29th</td>
<td>29th</td>
<td>29th</td>
<td>29th</td>
<td>29th</td>
</tr>
<tr>
<td>Surface temp. (°C)</td>
<td>0.0</td>
<td>0.1</td>
<td>0.2</td>
<td>0.3</td>
<td>0.4</td>
<td>0.4</td>
<td>0.2</td>
</tr>
<tr>
<td>Air temp. (°C)</td>
<td>−0.6</td>
<td>−0.4</td>
<td>0.0</td>
<td>0.7</td>
<td>1.2</td>
<td>0.4</td>
<td>0.2</td>
</tr>
<tr>
<td>Cloudiness</td>
<td>9</td>
<td>9</td>
<td>6</td>
<td>1</td>
<td>1</td>
<td>10</td>
<td>9.5</td>
</tr>
</tbody>
</table>

**ii) Seasonal and yearly change of oceanographical conditions**

As has been stated above, we have not enough data to adequately discuss seasonal and yearly changes of sea conditions. Concluding from all available data, the yearly change seems smaller than the seasonal change.
carried out at nearly the same point in different years show that they resemble each other greatly, as shown in table 2.

Table 2. Comparison of two oceanographic observations carried out at nearly the same point in different years. (After SUGIURA, J. 1950)

<table>
<thead>
<tr>
<th></th>
<th>Location</th>
<th>Date of observation</th>
</tr>
</thead>
<tbody>
<tr>
<td>St. 1</td>
<td>63°39' S, 152°34'E</td>
<td>December 26, 1946</td>
</tr>
<tr>
<td>St. 2</td>
<td>64°13' S, 153°36'E</td>
<td>December 18, 1948</td>
</tr>
<tr>
<td>Depth (m)</td>
<td>Water temperature (°C)</td>
<td>Salinity (%o)</td>
</tr>
<tr>
<td></td>
<td>St. 1</td>
<td>St. 2</td>
</tr>
<tr>
<td>0</td>
<td>-0.4</td>
<td>-0.9</td>
</tr>
<tr>
<td>25</td>
<td>-1.03</td>
<td>-0.67</td>
</tr>
<tr>
<td>50</td>
<td>-0.40</td>
<td>-1.26</td>
</tr>
<tr>
<td>100</td>
<td>+1.29</td>
<td>+1.41</td>
</tr>
<tr>
<td>400</td>
<td>+1.81</td>
<td>+1.80</td>
</tr>
</tbody>
</table>

Variation of various elements in the upper surface water during the years 1949 to 1952 is shown in the following table:

Table 3. Yearly variations of elements in the upper surface water taken from averages of all observations.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Water temp. (°C)</td>
<td></td>
<td>-0.16</td>
<td>-0.77</td>
<td>-0.15</td>
<td>-0.10</td>
</tr>
<tr>
<td>Chlorinity (%o)</td>
<td></td>
<td>18.43</td>
<td>18.60</td>
<td>18.63</td>
<td>18.87</td>
</tr>
<tr>
<td>Thickness (m)</td>
<td></td>
<td>32</td>
<td>40</td>
<td>41</td>
<td>58</td>
</tr>
<tr>
<td>Number of observations</td>
<td></td>
<td>12</td>
<td>11</td>
<td>4</td>
<td>6</td>
</tr>
</tbody>
</table>

Concerning the seasonal change we can not determine exactly because it is difficult to separate those changes due to time and those due to location. Generally speaking, surface temperature reaches its maximum in January and sur-
face chlorinity reaches its minimum in February. (SUGIURA, J, 1950)

(3) **Watermasses of the Antarctic Ocean**

As has been stated by H. U. SVERDRUP, the watermasses in the Antarctic Ocean, not deeper than 600m, consist of two kinds, namely:

(a) Antarctic surface water
(b) Antarctic circumpolar water

In addition to these two masses, the Antarctic bottom water also exists according to the “Discovery Report.” Our Japanese fleet has not observed this water yet.

For the purpose of water mass analysis, the T-Cl diagram as shown in figure 3 is based on all subsurface oceanographic observations carried out on board our whaling ships.

![T-Cl diagram](image)

**Fig. 3.** T-Cl diagram for the Antarctic Ocean based on all oceanographic Observations of the Japanese whaling fleet (1946-'52 seasons).

In this diagram, A₁ and A₂ represent the upper surface water in lower and higher latitudes respectively. B represents the under surface water, and C the circumpolar water, respectively.

The upper surface water is distinguished by its rather high temperature caused by solar radiation and its low chlorinity resulting from melting of ice.
To represent the horizontal distribution of this upper surface water, the isothersms at 25m deep are shown in figure 4, and 5, based on the data of 1950–1951 seasons.

A glance at these figures shown the existence of the warm water penetration southward in the vicinity of the points, 63.5°S, 119°E and 68°S, 171°W. The depth of the core of under surface water is found to be about 50–75m, but it often reaches more than 100m. In these areas the circumpolar water is insignificant and consequently, the under surface water is predominant. The insignificance of the Antarctic circumpolar water may be attributed to the following two causes:

(a) In those areas near the Antarctic continental shelf, the Antarctic circumpolar water is displaced by the under surface water to an increased depth.

Fig. 6a. Relation between the chlorinity and the distance from the pack-ice line.

Fig. 6b. Relation between the water temperature and the distance from the pack-ice line.
(b) As these areas are situated near the center of small clockwise circulation (having the diameter of ca. 100 nautical miles), Antarctic circumpolar water subsides and the under surface water extends to a considerable depth.

(4) Variation of water temperature and chlorinity according to latitude

Water temperature and chlorinity varies according to the distance from the pack-ice line. In other words, they vary roughly with latitude. In figure 6a and 6b, relations between the water temperature, the chlorinity, and the distance from the pack-ice line are shown, based on the data of the 1951-'52 season.

Fig. 7a.

Fig. 7b.

Fig. 7c.

Figs. 7a, 7b and 7c. Stream-lines by dynamic calculation (Jan.-Feb., 1949). Figures show the deviation of dynamic depth, assumed zero at the 600m layer. (Oceanographical Section, SUGIURA, KUGA, 1949).
From these figures we see that water temperature and chlorinity increase gives us parabolas, if plotted on graphs, as the distance from the pack-ice line increases. They drop suddenly in the area of 100 nautical miles from the pack-ice line.

(5) Description of current in the Antarctic Ocean

The inherent difficulty of observing deep oceanographical conditions in many stations results in few data being available for dynamic calculations. However, using the data of oceanographic observations in the 1948-1949 season, SUGIURA, J. and Y. KUGA have calculated the density current in the vicinity of Scott Island. The results are shown in figures 7a, 7b, and 7c each representing the density current of 0m, 75m, and 300m respectively. In calculating the density current, the motionless layer was assumed to be at 600m. The coverage of the observations was between 65°-70° S in latitude, and 170° E-170° W in longitude. Glancing at these figures we see that the direction of current does not vary appreciably according to depths, but its velocity decreases as the increases.

The direction of current to the north of 67° S was usually eastward, and to the south of 67° S, a southward flow along the 180° meridian prevailed. Furthermore, northward flow along the 175° W line was found and to the east of the 170° W line southward flow was seen. The velocities of these currents in the vicinity of 68.5° S, 173° W are 0.3 knots at the surface, 0.3 knots at 75m layer, and 0.1 knots at 300m layer respectively.

These calculated current patterns show somewhat different features than the Japanese Hydrographic Chart # 6102. But, these are the observations of only one season, and the mean state over long periods may differ somewhat from this result.

(6) Dissolved Oxygen

Dissolved oxygen was measured by Winckler's method on board. Vertical distribution of oxygen at one of the representative station is as follows:

Date: January 10, 1952; Location: 68°44’ S, 170°00’ W

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>0</th>
<th>10</th>
<th>25</th>
<th>50</th>
<th>75</th>
<th>99</th>
<th>141</th>
<th>197</th>
<th>291</th>
<th>382</th>
<th>473</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dissolved Oxygen (cc/L)</td>
<td>8.36</td>
<td>7.69</td>
<td>8.41</td>
<td>8.46</td>
<td>7.59</td>
<td>6.27</td>
<td>5.86</td>
<td>4.93</td>
<td>4.54</td>
<td>4.57</td>
<td>4.71</td>
</tr>
</tbody>
</table>

From this, we see that oxygen exceeds 8 cc/L at the 0-50 m layer, and decreases to 7.5 cc/L at 75 meters and to 4.5 cc/L at greater depths. The first spring layer is found at the depth of 50-75m, and the second one is seen at about 150m. The layer of minimum oxygen content is usually encountered at the depth of 300-400 m.
(7) Colour of the sea and the transparency

Colour of the sea was measured by Forel's standard colour scale. The frequency of colour of the sea in the Antarctic Ocean during 1946-1952 seasons is as follows:

<table>
<thead>
<tr>
<th>Colour of the sea</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Times observed</td>
<td>6</td>
<td>6</td>
<td>49</td>
<td>60</td>
<td>28</td>
<td>12</td>
</tr>
</tbody>
</table>

From this we see that the colours 3 and 4 appear most frequently in the Antarctic Ocean.

Transparency was measured by Secchi disc. In the Antarctic Ocean its value is usually 10-15m, having a maximum of 23m, and a minimum of 5m.

6. Relation between sea condition and whaling

One of the most important aims of our oceanographic observation in the Antarctic Ocean is to clarify the relations between sea conditions and whaling. Unfortunately, no concrete relations have been established as yet. However, it is usually believed by seamen that the boundary of two currents is a good whaling ground, even in the Antarctic Ocean.

Good whaling has been carried out in the following regions:

(a) The region where the warm upper surface water penetrates deeply,

(b) The region where the warm upper surface water flows southwards.

In the homogeneous water area, good whaling is not expected. The relation of between whaling and distribution of chemical components, plankton settling volume and the colour of the sea, etc. is uncertain.

7. Acknowledgements

The writers express their appreciation to those who have contributed to the information contained in this paper: to Dr. M. NAKANO, Meteorological Research Institute, for his supervision and suggestions; to Mr. J. R. COCKLE, who kindly read this paper before printing; to Mrs. M. HANZAWA and Miss T. YASUKAWA for their assistance in preparing tables; and finally to the members of the observing staff of the Japanese Antarctic whaling fleet, who collected and analyzed the data.
8. References

(a) Observational data

Observations taken on board Japanese Antarctic Whaling Ships from November 1946 till April, 1951. The Results of Marine Meteorological and Oceanographical Observations, Special Number. Jan., 1952 (C.M.O.)

(b) Reports