Solar Radiation and Stability of the Undersurface of Sea Ice Governing Ice Algal Proliferation

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Ice Algae の繁殖を支配する条件としての日射と海氷下面の安定度

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要旨：海氷の藻類による着色は，昭和基地周辺で秋と春の2回起こる．中緯度にあるサロマ湖のトエトコでも冬期に着色現象が認められる．昭和基地の秋の着色現象とトエトコの着色現象の起こる環境には共通点があるように思われ，主要環境条件と考えられる両地方の日射量と海氷下面の安定度とを比較検討した．

昭和基地の秋の藻類増加は3月始めから3月末までの間に，トエトコでは1月末から2月末までの間に起こると考えられる．この時期の日射量は1500〜2500 cal/cm²/10 days で，両地域に差が認められない．また，昭和基地では，10日間の平均気温が $-6°$ から $-9°C$ で，海氷の成長も溶解もほとんど認められず，海氷下面は安定していた．トエトコの気温は昭和基地よりやや低めであるが，昭和基地との差は少なく，海氷下面は安定していたと考えられる．

さらに，藻類の増殖に直接関与する海氷下端に達する日射量を測定した．透過日射量の雪面日射量に対する割合は，海表面の雪の多少により，4〜36% と変化した．

***Abstract*:** The coloration of sea ice by the ice algae occurred in austral autumn and spring at Syowa Station, Antarctica and in winter at Toetoko in Lake Saroma, Japan. The ice algal proliferation at both localities seemed to proceed through a similar process and under common environmental conditions. The solar radiation and the stability of the undersurface of sea ice as principal factors were compared between the two localities, particularly during the proliferation period of ice algae. Ordinarily it seemed that the ice algae proliferated between the beginning of March and the end of March at Syowa and from the end of January to the end of February at Toetoko.

The amount of solar radiation supplied during the algal proliferation period ranged from 1500 to 2500 $cal/cm^2/10$ days. No significant difference in the amount of solar radiation was recognized between Syowa and Toetoko. The mean air temperature ranged from $-6°$ to $-9°C$ at

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Syowa Station. The sea ice did not grow or melt and its undersurface was stable during the algal proliferation period. At Toetoko, the temperature was between −7° and −8°C and the stability of the undersurface of sea ice was observed. The amount of solar radiation penetrating through the sea ice was examined at Toetoko. The percentage of penetrated solar radiation to the incident solar radiation varied from 4 to 36% depending upon the surface condition of the sea ice.

1. Introduction

The coloration of the sea ice by the dense population of ice algae is well known in the Arctic and the Antarctic Oceans. Most of the workers have dealt with the ice algal proliferation from spring to summer in the polar oceans (ALEXANDER, 1979; BRADFORD, 1978; HORNER, 1977). However, the present author reported that the colorations were observed at the bottom of the sea ice in both autumn and spring in the Syowa Station (69°00′S, 39°35′E) area, Antarctica (HOSHIAI, 1972, 1977, 1981). Recently, HOSHIAI and FUKUCHI (1981) have confirmed that the coloration occurred in the bottom layer of the sea ice in winter at Toetoko (44°11′N, 143°45′E) in a lagoon, Lake Saroma, Hokkaido, Japan. They concluded that the proliferation of algae at Toetoko progressed through the same process as at Syowa Station in autumn. Ordinarily it seemed that the ice algae proliferated between the beginning and the end of March at Syowa and from the end of January to the end of February at Toetoko (HOSHIAI, 1981; HOSHIAI and FUKUCHI, 1981). Accordingly, it seems that there are common environmental factors which govern the ice algal proliferation at both localities. The solar radiation and the stability of the undersurface of the sea ice as the principal elements are dealt with in this paper.

2. Materials and Methods

Continuous measurements of the incident solar radiation on the sea ice and the radiation penetrating through the sea ice were made from February 27 to March 9, 1980, off the pier of the Toetoko harbor. A pair of pyranometers, MS 800 Type of Eko Seiki Co., with the filter of the spectral range from 305 to 2800 nm was used for the measurement. A sensor was set on the sea ice and another, submersible sensor, was suspended about several centimeters beneath the undersurface of the sea ice.

Moreover, the data of the solar radiation and the air temperature obtained at the Abashiri Meteorological Observatory and at Syowa Station were employed to supplement the results obtained by the present author. Abashiri is about 50 km southeast of Toetoko, but the two places seem to be situated within a locality of the same weather.

3. Results and Discussion

3.1. Incident solar radiation on the sea ice

The measurement of solar radiation was made from February 27 to March 9, 1980, except on February 29 when the sensor was covered with snow. The amount of incident solar radiation on the sea ice at Toetoko ranged from 185.1 to 369.8 cal/cm²/day and its mean was 312.5 cal/cm²/day. The results of Toetoko were compared with the data obtained at the Abashiri Meteorological Observatory during the same period.

A good correlation as shown in Fig. 1 was recognized between the data of Toetoko and Abashiri. Therefore, it was assumed that the values of solar radiation at Abashiri could represent the solar radiation at Toetoko.

The amount of solar radiation supplied for the coloration by the ice algae at Toetoko was compared with that of Syowa Station. For convenience' sake, the amount of daily radiation was summed up for every 10 day period before and after a fixed date, X day. As the X day, February 15 and March 20

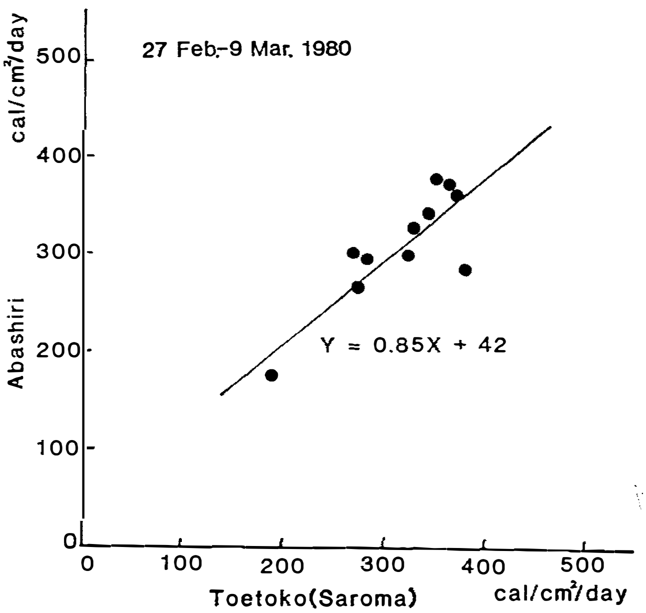

Fig. 1. Correlation between the solar radiation at Toetoko and that at Abashiri.

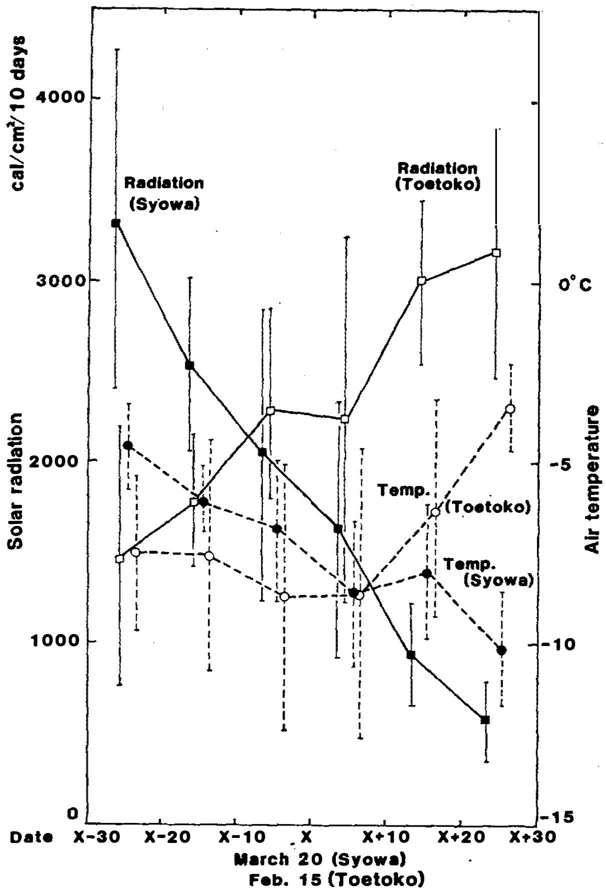

Fig. 2. Solar radiation and air temperature at Syowa Station and Toetoko.

—■— *The mean of the total amount of daily radiation during a 10 day period, Syowa, 1970 to 1975.*

—□— *The mean of the total amount of daily radiation during a 10 day period, Toetoko, 1975 to 1980.*

···●··· *The average of the means of daily mean air temperature during a 10 day period, Syowa, 1970 to 1975.*

···○··· *The average of the means of daily mean air temperature during a 10 day period, Toetoko, 1975 to 1980.*

were empirically selected at Toetoko and Syowa, because the colored layer of the sea ice had become discernible by February 15 at Toetoko and by March 20 at Syowa Station (HOSHIAI, 1981; HOSHIAI and FUKUCHI, 1981). The data of Abashiri which were substituted for those of Toetoko were obtained from 1975 to 1980 and those of Syowa were acquired between 1970 and 1975. The mean of the total amount of daily radiation during a 10 day period between 30 days before and after the X day are given in Fig. 2 with the standard deviations. The solar radiation increased from 1500 to 3200 cal/cm^2/10 days at Toetoko. On the contrary at Syowa it decreased from 3300 to 600 cal/cm^2/10 days. However, between 20 days before and 10 days after the X day, the values ranged from 1500 to 2500 cal/cm^2/10 days and the amount of 10 day's solar radiation at Toetoko did not differ from that of Syowa.

3.2. Stability of the undersurface of sea ice

It was ascertained by the frequent observations in 1970 and 1975 that the thickness of the new ice about 30 cm thick hardly changed and the undersurface of the sea ice remained stable for about two months, March and April, in the Syowa Station area. The sea ice grew less than 5 cm during the two months and the average of daily mean air temperature in the 10 day period decreased $-5°$ to $-10°$C. The stable bottom of the sea ice seemed to provide a substratum for the ice algal proliferation.

Twice and three times measurements of the sea ice thickness had been carried out at Toetoko at intervals between February and March in every year from 1977 to 1981. It was recognized that the sea ice thickness which had grown to 20 to 40 cm scarcely varied unless snow fell heavily in a short period. The undersurface of the sea ice was stable, even though the sea ice was depressed by snow accumulated. To supplement the scarcity of the observations at Toetoko, the data of the daily mean air temperature of the Abashiri Meteorological Observatory were employed and they were compared with those of Syowa Station, because it is known that the growth of sea ice is governed mainly by the air temperature. The sea water temperature remained at about freezing point during the observations. The six years' averages of the 10 day's means of daily mean air temperatures between 30 days before and after the X day are also shown in Fig. 2 with the standard deviations. At Syowa, the average decreased from $-5°$ to $-10°$C towards winter. At Toetoko it decreased from $-7°$ to $-8°$C till the end of February and then it recovered to $-3°$C in the middle of March. Between 20 days before and 10 days after the X day, though the averages of Toetoko were lower than those of Syowa Station, the difference in the average values at the two places was not significant.

3.3. Solar radiation beneath the sea ice at Toetoko

The solar radiation which penetrates to the bottom of the sea ice governs the proliferation of ice algae. Consequently, it is valuable to measure the solar radiation which penetrated through the sea ice. BUNT and LEE (1970)

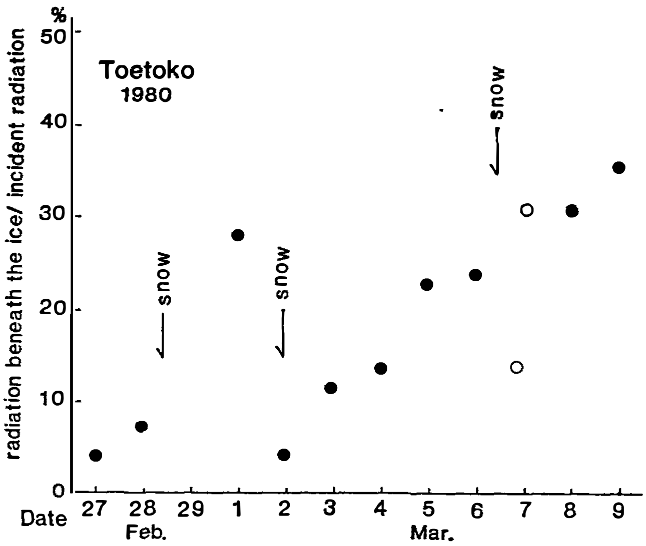

Fig. 3. Percentage of radiation penetrating through sea ice to incident radiation, observed at Toetoko from February 27 to March 9, 1980. The percentages before and after the sweeping of snow on March 7 are shown by open circles.

and MAYKUT and GRENFELL (1975) have noted that the amount of radiation penetrating through the sea ice fluctuated depending upon the surface condition of the sea ice rather than its thickness. A preliminary measurement of radiation beneath the 35 cm thick sea ice was carried out at Toetoko. The amount of radiation beneath the sea ice ranged from 15.1 to 110 cal/cm^2/day. The daily mean value of the percentage of the penetrated radiation to the incident solar radiation fluctuated from 4 to 36% depending mainly on the snow accumulation (Fig. 3). At noon, March 7, the percentage varied from 14.3 to 31.0% before and after sweeping of the newly accumulated snow of 1 cm depth. The present result agreed with the previous two papers.

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