Sea Ice Extent and Global Warming in the Okhotsk Sea

Fumihiko Nishio
(Hokkaido Univ. of Education)
Kohei Cho
(Technology and Research Infomation Center, Tokai Univ.)

Abstract

Sea ice in the Okhotsk Sea is constrained by land and is existing in the most southern region in the Northern Hemisphere where no sea ice survives in summer season. The interannual variability of the total sea ice extent in winter is from approximately 1.3 x 10^6 km^2 (maximum in 1978 and 1979) to 0.7 x 10^6 km^2 (minimum in 1984).
Investigation on the interannual variability of sea ice extent in the Okhotsk Sea and the sea surface temperature of the eastern equatorial Pacific Ocean suggested the negative correlation between the larger ice extent of the Okhotsk Sea and El Nino, and followed by the smaller ice extent of it after the El Nino events, that is, Anti-El Nino events(occasionally so called La Nina events).
El Nino events could influence the middle latitude anti-cyclone. Namely, the middle latitude westerlies in the region of the North Pacific Ocean become more zonal wind. The stress of intensified westerly winds drive the sea ice to the overall area of the Okhotsk Sea.
In this study, satellite passive microwave data, mainly DMSP-SMM/I data(1987-1991), were used to calculate the interannual validation of sea ice extent in this area. The derived interannual validation graph showed a small peak in each summer under the ice-free condition. In the former analysis, this phenomena was explained as land effect. However, we supported that this phenomena was mainly caused by the high water vapor in the atmosphere over the Okhotsk Sea in summer season. Considering this effect, we have re-evaluated the trend of the sea ice extent in this area and compared with El Nino/La Nina events.
We could result in almost the same interannual trend of sea ice extent, however, the smaller sea ice extent of the Okhotsk Sea, which was obtained by the former algorithm of sea ice concentration.
It also becomes very important for monitoring the interannual variability of sea ice extent in Okhotsk Sea because Noda (1994) pointed out that a notable CO_2- induced warming has firstly appeared around the Okhotsk Sea , although the model resolutions are not enough to resolve local climate changes and sea ice model is simple. However, these transient response is plausible because the Okhotsk Sea locates at the southernmost boundary of sea ice formation in the Northern Hemisphere. Therefore, further studies on sea ice extent and El Nino events will be important and continued by satellite microwave data.

Introduction

Sea ice is present over about 7 % of the Earth's ocean surface. Its presence or absence at any given time has a profound effect on the Earth's radiation budget because the albedo of sea ice (which is usually snow covered) is dramatically higher than that of open water. Additionally, sea ice is an insulating layer between the ocean and the atmosphere, that is, heat loss through open water can be 10-100 times greater than heat loss through sea ice. Sea ice in the Southern Hemisphere typically varies from about 4x10^6 km^2 to 21x10^6 km^2

seasonally and is not constrained by land, while the variability of sea ice in Northern Hemisphere is from approximately 8×10^6 ㎢ to 15×10^6 ㎢. Arctic sea ice is constrained by land and is thus thicker (3-4 meters average) than the sea ice surrounding Antarctica (0.5-1 meters in average). Less than one eighth of the sea ice survives the Southern Hemisphere summer, while nearly one half survives the Northern Hemisphere summer. Therefore, as in the case of snow, the large surface to volume ratio of sea ice permits rapid response to climate change.

Okhotsk sea ice

Sea ice in the Okhotsk Sea is constrained by land and islands as shown in Fig. 1 and is existing in the most southern region of Northern Hemisphere winter.

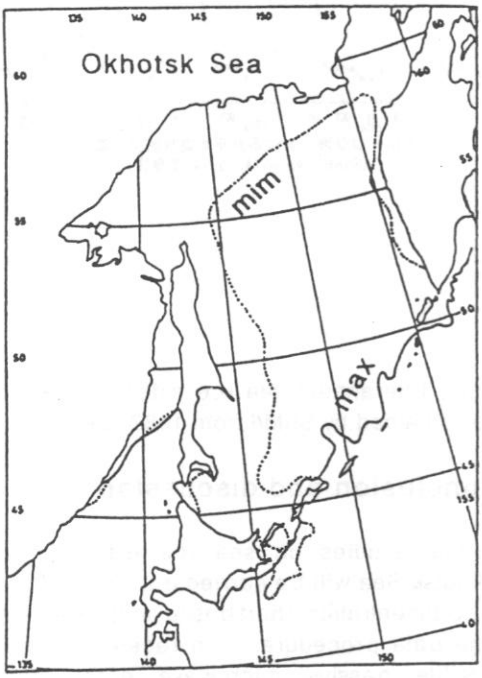

Fig.1. Maximum and minimum interannual sea ice extent in the Sea of Okhotsk.
Sea Ice Extent
--- Maximum : February 28, 1978
..... Minimum : February 29, 1984

No sea ice survives the Northern Hemisphere summer, which is predominantly first-year ice, while the variability of the total areal extent of sea ice in winter is interannually from approximately 1.3×10^6 ㎢ (maximum in 1978 and 1979) to 0.7×106 ㎢ (minimum in1984) as shown in Fig.2. Not only is the extent of sea ice cover important, but the presence of leads and polynyas is significant to the energy budget of the ice-covered ocean and to the local and regional climatology for changing the atmospheric circulation. It does not appear likely that sea ice thickness can be determined directly using satellite data, but ice concentration can be used to infer the percentage of open water.

Even thin sea ice has a significant influence on the heat exchange between the ocean and the atmosphere. The ice growth and salt rejection to the ocean depend strongly on ice thickness, and during this winter period biological production can be affected by the growth of sea ice and shortwave radiation to the upper ocean.

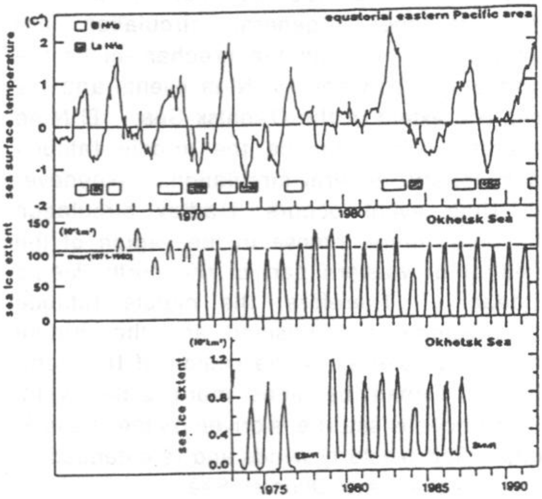

Fig.2. Interannual variability of sea ice extent

in the Okhotsk Sea and the sea surface temperature of eastern equatorial Pacific Ocean (upper figure). Sea ice distributions are obtained by various methods as satellite (NOAA, GMS and MOS-1), aircrafts, ships and coastal radars (middle figure), and SMMR (lower figure). It shows the lower sea ice extent in 1971, 1974, 1984 and 1989 is significantly correlated with La Nina events which are followed by El Nino.

Sea ice extent and sea surface temperature

Some results are discussed on the interannual variability of sea ice extent in the Okhotsk Sea and sea surface temperature of the eastern equatorial Pacific Ocean, which is negatively correlated with temperature of the western equatorial Pacific Ocean. In Fig.2, sea ice distributions are obtained by various methods as satellite (NOAA, GMS and MOS-1), aircraft, ships, coastal radars (middle figure) and SMMR (lower figure). Figure 2 shows the relatively lower sea ice extent in 1971, 1984 and 1989 is significantly correlated with La Nina events (anti-El Nino) which is followed by El Nino.

At present it becomes clear that the variations of atmospheric general circulation are important to explain the mechanism of the connection between La Nina events and the sea ice extent in the Okhotsk Sea. El Nino events could influence the middle latitude atmospheric general circulation. Whenever El Nino event occurs, Hadley circulation becomes more intense in the region of the central or western part of the north Pacific Ocean. Therefore, the middle latitude anti-cyclone is intensified and the middle latitude westeries in the region of the north Pacific Ocean becomes more zonal wind. Consequently sea ice is driven by the stress of intensified westerly winds and is extended in the overall area of Okhotsk Sea.

On the other hand, when La Nina event occurs, the sea surface temperature is higher than it during El Nino events in the western Pacific Ocean. Then, the middle latitude cyclone is intensified and the middle latitude southerlies becomes more southerly wind. In consequence, sea ice drifts southward to the Okhotsk Sea Coast of Hokkaido and sea ice extent during La Nina is less than it in the normal winter. Further studies on sea ice extent and El Nino events will be continued by satellite data.

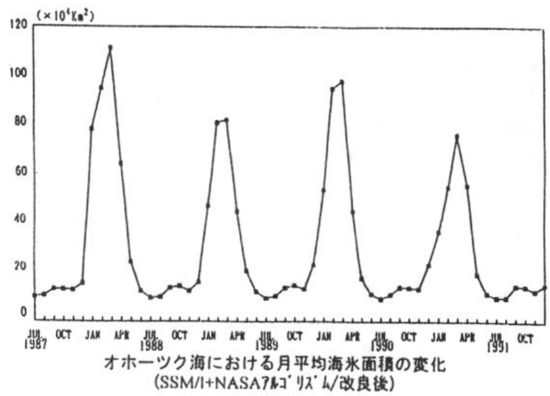

Fig.3. Interannual sea ice extent of Okhotsk Sea obtained by SSM/I from 1987 to1991.

Conclusion and discussion

Further studies on sea ice extent in the Okhotsk Sea will be carried out by SSM/I total ice concentration chart based on the near-real time data procedure. In recent sudies on satellite passive microwave data, mainly DMSP-SMM/I data (1987-1991), were used to calculate the interannual validation of sea ice extent in this area. The derived interannual validation graph showed a small peak in each summer under the ice-free condition. In the former analysis, this phenomena was explained as land effect. However, we supported that this phenomena was mainly caused by the high humidity in the atmosphere over the Okhotsk Sea in summer season. Considering this effect, we have reevaluated the trend of the sea ice extent in this area and compared with El Nino/La Nina events.

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