6.8 Does the fresh water supply from the Amur River flowing into the Sea of Okhotsk affect sea ice formation?

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1. INTRODUCTION

The Okhotsk Sea is the one of the southernmost ice-covered oceans in the Northern Hemisphere. It has been blindly believed that the inflow of much fresh water from the Amur River plays an important role in the formation of ice over the Okhotsk Sea. Because low saline water due to the inflow of the fresh water from Amur River suppresses the deep convection and promotes freezing..

Ogi et al. (2001), however, found the evidence that the Amur discharge is strongly negatively correlated with the ice extent by using time series analyses (Figure 1). This means that in winters following summers in which the amount of the discharge was below normal, the ice in the Okhotsk covers abnormally large areas and vice versa. However, the cause of the abnormal relationship between the Amur River water and the sea-ice in the Sea of Okhotsk is an open question. The purpose of this study is to show possible mechanisms of this negative relation.

2. DATA

Following data are used in this study; 1) the Amur River run-off water data issued by GRDC (Global Runoff Data Center) is from 1964 to 1993, 2) Sea ice extent data in the Okhotsk issued by the Japan Meteorological Agency (JMA) from 1971 to 1996, 3) Sea surface temperature (SST) data in the Okhotsk issued by JMA from 1964 to 1995.

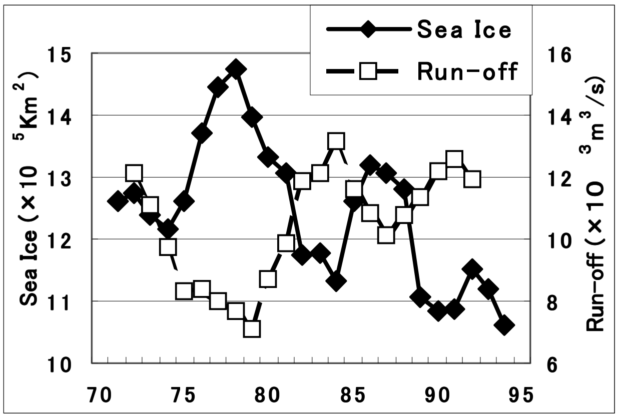

Figure 1. The sea ice extents of the Okhotsk Sea and amount of the Amur River run-off water (three-year running mean).

3. RESULTS AND DISCUSSION

A possible cause of this opposite relation is the influence of the sensible heat advection from the river. If the summer temperature of the river is higher than that of the Okhotsk, the discharge brings about the advection of warm water into the surface layer of the Okhotsk. Because the low-density warm fresh water can easily spread on the surface layer of the sea in the summer, the warm SST due to the discharge can reduce the potential for freezing in the following winter. This interpretation is consistent with the facts that the interannual variation of the discharge is positively correlated with summer-time SST in the northwestern Okhotsk. Because the northwestern part is known to be the main ice-production area (Martin et al. 1998), from which the ice moves and spreads towards the south, the SST in this area is able to influence the ice extent throughout the Okhotsk. The distribution of the correlation coefficient between summertime SST in the Okhotsk and the discharge exhibits a gradual eastward weakening, reflecting the eastward penetration and dilution of the warmer river water. Because the topography of the Amur is shallow, slow-moving and meandering, it is, therefore, accepted that the water parcels of the Amur have plenty of time to equilibrate to the surrounding summer mean temperature, which is obviously higher than the SST in the Okhotsk, since the heat capacity of the continent is, in general, smaller than that of surrounding oceans.

We roughly estimate the annual water budget in the Okhotsk as follows. Assuming that the runoff water spreads out uniformly within the hatched northwestern area where there are high correlations between the discharge and the SST, and that it accumulates on the surface of the ocean without vertical mixing with the underlying saline water, the annual accumulation depth of runoff water will range from 2.6 to 5.0 m/year. If the temperature difference between the river and the ocean is 10℃, fluxes ranging from 42 to 81W/m^2 are needed in order to release the all the excess heat into the atmosphere over a period of a month. Therefore, the heat difference between a large discharge year and a small discharge year is 39W/m^2. This value is comparable to the latent and sensible heat released into the atmosphere in the beginning of the winter. According to the ECMWF (European Centre for Medium-Range Weather Forecasts) analysis data for the heat flux, the average surface heat flux in the northwestern OK in November 1991 through 1998 is about 205 W/m^2, and the standard deviation is about 41 W/m^2. Because this value is mainly influenced by the interannual variation of atmospheric conditions, the effect of the heat from the river can be comparable to atmospheric variability in the beginning of winter. However, detailed analyses of the heat budgets using numerical methods, such as a box ocean model, should be done in the future study in order to quantify the river effect.

Another possible cause of the negative correlation between the river discharge and the sea-ice could be a mutual relationship to some other variable. Both the runoff and the sea-ice exhibit decadal time-scale variations with a slightly increasing linear trend of the river discharge, accompanied by a declining trend in the sea-ice. If, for example, the summertime atmospheric circulation patterns that directly determine the precipitation over western Siberia are related to the wintertime atmospheric circulations that influence the ice extent, such as the Aleutian low, then we can expect the underlying summer-to-winter connection in the atmospheric patterns also have variability on the decadal time scale. However, these good correlations suggest that there might be undiscovered inter-seasonal connections, and we should make sure of the existence of the inter-seasonal linkage in a future study. Both the indirect large scale influence and the direct sensible heat can contribute to the strength of the relationship between the discharge and the ice.

4. REFERENCES

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