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Lee, Ho Jin
Division of Marine Environment & Bioscience, Korea Maritime University

Choi, Hee Jin
Korea Institute of Ocean Science and Technology

Park, Jae-Hun
Korea Institute of Ocean Science and Technology

Park, Young Gyu
Korea Institute of Ocean Science and Technology

他

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A Coupled Ice-Ocean Model for the East/Japan Sea

Ho Jin LEE*1, Hee Jin CHOI*2, Jae-Hun PARK*2,
Young Gyu PARK*2 and Sang Yeob KIM*1
E-mail of corresponding author: *hjlee@hhu.ac.kr*
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Abstract

We investigate effects of the sea ice on the low salinity Liman Cold Current (LCC) flowing along the Russian coast in the northern East/Japan Sea (EJS) using an ice-coupled Ocean General Circulation Model, ROMS(Regional Ocean Modeling System). The modeled sea ice in the Tatar Strait shows a maximum extent in February and reproduces the variation of sea ice extent reasonably, though the model appears to underestimate the sea ice concentration and volume fluxes. Salinity anomaly on the surface of σ_θ=27.2 kg/m^3 along the Russian coast shows a tendency to become negative when the sea ice volume in the northern EJS increases.

Key words : *Ice-coupled OGCM, ROMS, East/Japan Sea, Sea Ice*

1. Introduction

The East/Japan Sea (EJS), a marginal sea of the northwestern Pacific Ocean, has been considered a miniature ocean, because its circulation system and water mass formation are similar to those of the major open oceans. Another similarity to the open ocean is the existence of sea ice in the northern EJS, which can affect water property changes there.

Melted waters at the edge of sea ice can be an alternative source for the low salinity water in the northern EJS, especially during January to March when the Amur River has a near-zero minimum[1)]. Sea ice in Peter the Great Bay near Vladivostok seems to play an important role in deepwater formation through brine rejection in extremely cold winter of 2001[2)]. According to Park et al., sea surface temperature and salinity along the Russian coast in spring are highly correlated with the sea ice concentration in the Tatar Strait[3)].

Despite of its importance, the sea ice as well as Amur River input has been ignored in previous modeling studies. Besides, most of previous numerical simulations have used a relaxation scheme of sea surface salinity at the sea surface. The used salinity data, however, has an uncertainty due to lack of data in the northern EJS. In this study, we simulate the sea ice in the EJS using an ice-coupled ocean model and investigate its effects on the low salinity water transport along the Russian coast.

2. Model

The OGCM used in this study is the ROMS (Regional Ocean Model System) version 3.4, which is a three dimensional, s-coordinate, primitive equation ocean model (http://www.myroms.org). The sea ice module of the ROMS includes both sea ice dynamics and thermodynamics. The sea ice dynamics is based on an elastic-viscous-plastic (EVP) rheology including ice momentum equations[4,5)]. For ice thermodynamics, two ice layers and a single snow layer are used in solving the heat conduction equation[6)]. The snow layer possesses no heat content but plays a role as an insulating layer.

The model area covers the region 33°N−52°N, 126.5°E−142.5°E with grid resolution of 1/10°. A total of 50 s-coordinate levels are adopted along the vertical direction with enhanced resolution near the surface. We used the ETOPO2 data for the model bathymetry. Vertical mixing coefficients are calculated with the Mellor-Yamada turbulence closure scheme[7)]. The turbulent air/sea and air/ice fluxes are calculated by the bulk parameterization without any relaxation of SST and SSS[8)].

*1 Division of Marine Environment & Bioscience, Korea Maritime University
*2 Korea Institute of Ocean Science and Technology

The model has two inflow open boundaries, Jeju Strait and the cross-section between the Jeju Island and the west coast of Kyushu along the 33°N and has two outflow boundaries, Tsugaru and Soya Straits. Along all open boundaries, Flather and Chapman boundary conditions are used for barotropic normal velocity components and the sea surface elevation, respectively[9,10]. Temperature, salinity and baroclinic velocity components at open boundaries are calculated with a radiation condition[11]. For that, we used the 10-year (2001−2010) monthly mean RIAM real-time ocean forecasting data (http://dreams-i.riam.kyushu-u.ac.jp/vwp/). In addition to oceanic flows, four major tidal forcings (M_2, S_2, K_1, and O_1) are included along the open boundaries based on TPXO7. The Amur River flux is included at the northern end of the model domain[1].

We set constant temperature and salinity profiles for the initial condition using domain-averaged August data from the JODC. We used ECMWF forecast data with 0.5° resolution and ERA interim reanalysis data during the period of 1999−2008 to calculate sea surface fluxes as well as wind stress at the sea surface. After spinning up for 30 years with monthly mean atmospheric fields, we conducted a hindcast simulation from January 1, 1999 to the end of 2008 with a 12-hourly atmospheric forcing.

3. Results

Figure 1 shows the calculated sea ice concentration and the AMSR-E satellite data, which are 7-years (2002−2008) monthly mean fields. Both results show a similar evolution of sea ice in the northern EJS; sea ice begins to increase in December and reaches a maximum in February, and then decreases until April. It is notable that the model reproduces monthly variation of sea ice extents well in regions where the concentration is greater than 0.15 (Fig. 2). The differences between the simulation results and satellite measurements are less than 10% for January and March, although they become larger in April when sea ice coverage is relatively small.

However, model output shows a relatively lower concentration than the observed one. In February, the averaged concentration over the same area is about 0.42 for the model output and 0.74 for the ARMS-E data. The model seems to underestimate the sea ice concentration overall by about 40%.

Figure 3 shows 10-years (1999−2008) averaged sea ice velocity. We can see a clockwise movement of sea ice over the sea ice coverage which seems to be mainly driven by wind stress. The velocity becomes a maximum in January. It is noted that the sea ice velocity is faster

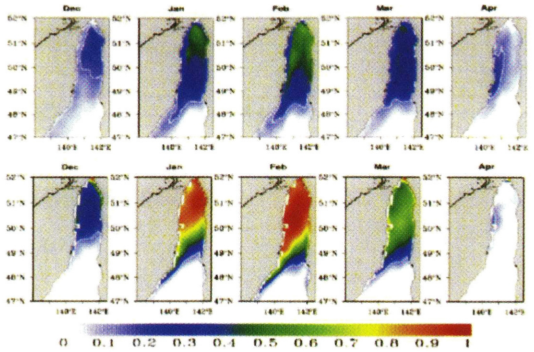

Fig.1 Monthly sea ice concentration for 2002−2008. The upper panel is model results and the lower is ARMS-E satellite data. The white line indicates sea ice concentration greater than 0.15.

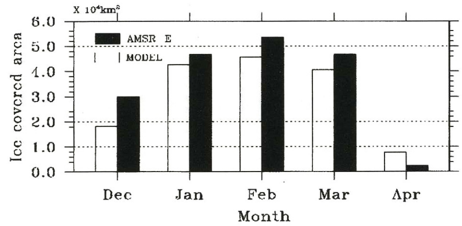

Fig. 2 Calculated sea ice extent from model (white) and AMSR-E data (black).

around the edge of sea ice coverage than the coast. The velocity is up to about 0.2 m/s around the edge.

This result is similar to the observed one by AVHRR thermal images taken in January 1994[1]. The calculated the sea ice velocity based on ice floes displacement was about 0.17 m/s around the sea ice edge and 0.05 m/s along the coast.

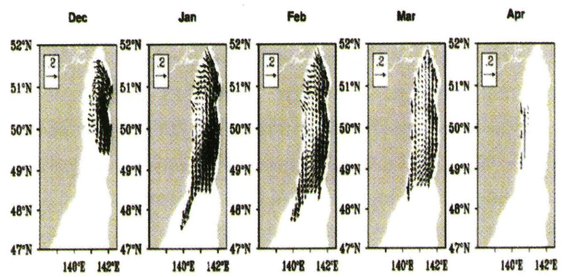

Fig. 3 Monthly sea ice velocity where sea ice concentration is higher than 15%.

In order to estimate a freshwater production by the sea ice, we calculated a sea ice volume flux in the northern EJS. We define the sea ice volume flux (Q_i) as follows:

$$Q_i = \int A \times h_i \times V_i \, dx, \qquad (1)$$

where A is the sea ice concentration, h_i is the sea ice thickness, and V_i is the sea ice velocity. Figure 4 shows calculated sea ice volume fluxes across the section along 50°N and 51°N. The volume flux at 50°N is about 2.7 km^3/month in January and becomes a maximum (3.3 km^3/month) in February when sea ice concentration shows a maximum.

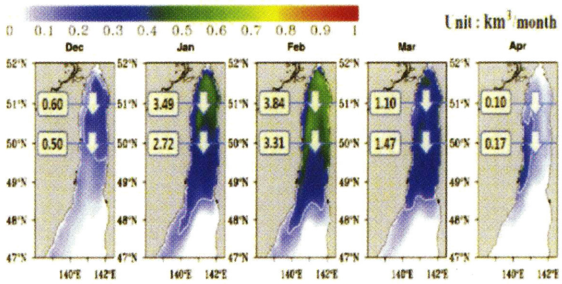

Fig. 4 Calculated sea ice volume flux along 50°N and 51°N. Colors indicate the sea ice concentration.

The model result is about 30% of the sea ice volume flux estimated by Martin and Kawase based on satellite images from 1992 to 1994[1)]. Their averaged flux shows the maximum in February and its value is about 11 km^3/month. The underestimate sea ice concentration and thickness in the model seem to cause the difference.

The sea ice in the Tatar Strait is supposed to affect the low salinity water, so called the Liman Cold Current (LCC), flowing along the Russian coast, which is a main source to the subsurface lower salinity water mass, the East Sea Intermediate Water (ESIW). To see the effect of sea ice on them, we compared salinity anomalies along the Russian coast and year-to-year variation of sea ice volumes in the Tatar Strait using a Hofmueller diagram (Fig.5). The salinity anomaly was calculated by

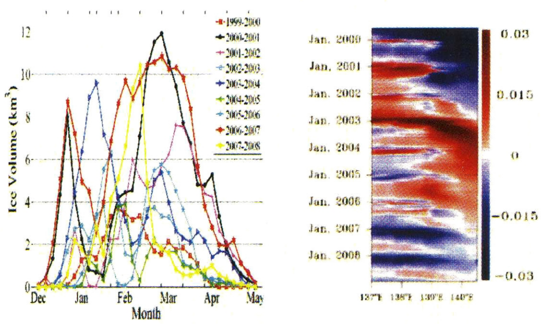

Fig. 5 Calculated sea ice volumes in the Tatar Strait (left) and Hofmueller diagram of Salinity anomaly on the σ_θ=27.2 kg/m^3 surface along the Russian coast (right).

removing the 10 years monthly-mean fields on the σ_θ=27.2 kg/m^3 surface, which is regarded as the middle of the ESIW.

It is noted that a negative salinity anomaly exists along the coast when the sea ice volume is relatively increased in February (for instance, 2001 and 2007). When the sea ice volume is lower than usual (2003, 2004, and 2005), a positive anomaly occupies along the coast. Therefore, model results indicate that the low salinity water flowing along the Russian coast might be affected by sea ice, although a more quantitative study would be necessary to clarify the correlation between the two.

4. Summary

The sea ice in the northern EJS has been simulated using an ice-coupled Ocean General Circulation Model. Compared with AMSR-E satellite data, model reproduced the sea ice extent and its variation well but underestimated the sea ice concentration by about 40%. As a result, the calculated sea ice volume flux is 70% lower than previous study[1)]. In spite of underestimated sea ice volumes, model results indicate that there are a sensible correlation between low salinity waters transported along the Russian coast and sea ice volume in the Tatar Strait. Further studies are necessary to more correctly reproduce the sea ice volume in the Tatar Strait and investigate its effect on the ESIW quantitatively using a statistical analysis.

References

1) S. Martin, and M. Kawase, J. Mar. Res. 141– 155 (1998)56.
2) L.D. Talley, V. Lobanov, V. Ponomarev, A. Salyuk, P. Tishchenko,I. Zhabin, and S. Riser, Geophys. Res. Lett., doi:10.1029/2002GL016451(2003)30.
3) K.A. Park, K. Kim, P.C. Cornillon, and J.Y. Chung, Geophys. Res. Lett.,doi:10.1029/2005GL025611 (2006)33.
4) E.C. Hunke, J. Comp. Physics, 18–38(2001)170.
5) E.C. Hunke, and J.K. Dukowicz, J. Phys. Oceanogr. 1849–1868 (1997)27.
6) G.L. Mellor, and T. Yamada, Rev. Geophys. Space Phys., 851–875(1982).20.
7) G.L. Mellor, and L. Kantha, J. Geophys. Res. 10,937–10,954(1989)94.
8) C.W. Fairall, E.F. Bradley, D.P. Rogers, J.B. Edson, and G. S. Young, J. Geophys. Res. 3747–3764(1996) 101.
9) D.C. Chapman, J. Phys. Oceanogr. 1060–1075

(1985)15.

10) R.A. Flather, Memoires de la Societe Royale de Sciences de Liege 141–164 (1976)6.

11) P. Marchesiello, J.C. McWilliams, and A.F Shchepetkin, Ocean modeling 1–20(2001)3.