## Variability of water and heat exchanges through the Bering Strait in numerical experiments with the NEMO/SI3 model assimilating observational data

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### Introduction

The most detailed representation about the variability of the dynamic structure of the ocean can be derived from the results of calculations using hydrodynamic models with the assimilation of available observational data. NEMO model (NEMO ocean engine) coupled with the thermodynamic sea ice model (The NEMO Sea Ice Working Group, 2018) is one of the most advanced and widely used ocean models. In the latest versions, starting from 4.0, it is possible to embed the AGRIF library (Blayo and Debreu, 1999), including also a sea ice model with several ice categories. The software of the library allows performing calculations simultaneously within a single task on several grids: a global, relatively coarsely resolved grid (hereafter "*host*"), is combined with a regionally confined, high-resolution grid (hereafter "*nest*") allowing for two-way interactions: the *host* not only provides boundary conditions for the *nest* but also receives information from the *nest*.

Within the framework of this approach, calculations were carried out to reproduce the circulation of the subpolar part of the Pacific Ocean. In particular, the model results allow tracing the characteristics of seasonal and interannual variability of water and heat exchange through the Bering Strait.

### Model configuration and data used

The combined grid area of the model consists of a *host* at 1×1° horizontal resolution within ORCA1 (362×332 nodes) and 75 vertical levels and an embedded *nest* at about 0.25° resolution, covering the subarctic part of the Pacific Ocean, the Bering Sea, the Alaska Bay, and also part of the Arctic basin up to latitude 80°N. The multi-category ice model SI3 included five thickness categories: <0.6 m; 0.6-1.3 m; 1.3-2.2 m; 2.2-3.8 m and > 3.8 m.

A numerical experiment with a two-grid configuration of the model domain forced by DFS5.2 (DRAKKAR Forcing Sets) included two stages: 1) the 6-year long spin-up integrations from 1995 to 2000, initialized with January temperature and salinity from the WOA13 Atlas and an ocean at rest, and 2) the ocean states at the end of the spin-up integrations are used to initialize the simulation for the period 01.01.2001–29.12.2015 assimilating data of vertical distributions of temperature and salinity of water by Argo buoys (ftp://ftp. ifremer.fr/ifremer/argo/geo), satellite measurements of SST (ftp://ftp.nodc.noaa.gov/pub/data.nodc/ pathfinder/Version5.2/) and data of sea ice extent (ftp://ftp.ifremer.fr/ifremer/cersat/products/gridded/psi-concentration/data).

Data assimilation was carried out using a sequential cyclic scheme (Zelenko et al., 2016) and three-dimensional variational analysis (Tsyrulnikov et al., 2010) with a 10-day assimilation window.

### Water and heat exchange through the Bering Strait

Water and heat exchange through the Bering Strait (that in the model domain is located in the *nest* with the horizontal resolution of 0.25°) is one of the key elements of global circulation, since the dynamics of the eastern Arctic and the adjacent North Pacific waters significantly depends on the rate of transports of mass, heat and salt through this strait.

The calculations show that the mass transport through the strait section is about 0.76 Sv (1 Sv=$10^6$ $m^3$/s) with a sufficiently large temporal variability reaching the maximum transport value up to 5.5 Sv (the root-mean-square deviation (RMS) is 0.90 Sv). There is a negative time trend of ~ –0.0227 Sv per year, indicating a slowdown in the rate of water inflow from the Pacific Ocean into the Arctic basin (Fig. 1a). The mean transport through the strait is in good agreement with the available measurements (0.8 Sv) (Roach et al.,1995; Woodgate et al., 2005) and with model values in similar works, e.g. see (Kinney et al., 2014).

Heat transport is characterized by a clearly pronounced seasonal variability that is superimposed by short-term variations (Fig. 1b). Its RMS of $1.90\times10^{13}$ W exceeds the average value of the heat transport for the whole period of $1.25\times10^{13}$ W against the backdrop of a slight negative trend of $-2.22 *10^{11}$ W per year.

Seasonal changes of the volume transport averaged for the period 2001–2015 are weak and the transport is most often directed from the Pacific Ocean to the Arctic basin with episodic changes in the direction of the flow (Fig.2a). Such changes of directions most often occur in the autumn-winter period (from October to January). The heat transport is most intense in the summer-autumn period from July to October, and its greatest interannual variability is in the period from May to December (Fig. 2b).

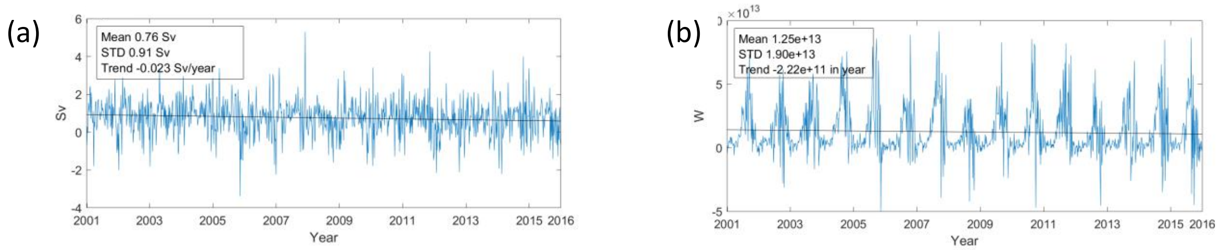


Fig. 1. The variability of volume transport (in Sv, 1 Sv=$10^6$ $m^3$/s) (a) and heat flux (in $10^{13}$ W) referred to reference temperature of –2.6°C (b) through the Bering Strait section according to the numerical experiment for 2001–2015. Positive values correspond to a transport from south to north.

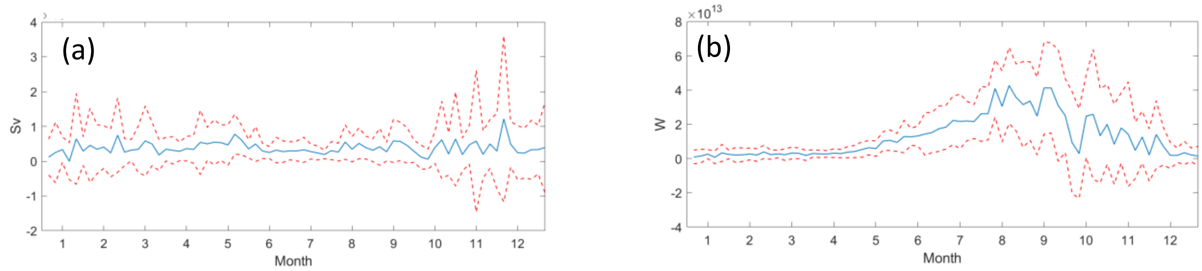


Fig. 2. Seasonal changes in water (a) and heat (b) exchanges through the Bering Strait averaged for 2001–2015 (blue lines). The red dashed lines show the standard deviations in water and heat transports.

**Summary**

The presented version of modelling the subarctic zone of the Pacific Ocean and the southeastern part of the Arctic with NEMO ocean model coupled with the SI3 sea ice model using the AGRIF library for nested grids together with data assimilation allows tracing the dynamics of water and heat exchange through the Bering Strait, which is one of the key regions of the interoceanic water exchange.

The model results are quite satisfactory when compared to observations and it shows the realism of the resulting model output of the data assimilation system with the detailing of individual water basin and, therefore, it indicates that such approach is promising for obtaining a detailed picture of the ocean states with moderate computational costs.

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