Water exchange between the Arctic Ocean and adjacent basins: Essential role of short-term variations

Alexander A. Zelenko and Yurii D. Resnyansky

Hydrometeorological Research Center of the Russian Federation,
Bol. Predtechesky per., 11-13, 123242 Moscow, Russia

E-mail: zelenko@mecom.ru

Mean structure and temporal variability of the water mass exchange between the Arctic Ocean and adjacent basins nave been studied basing on numerical experiments with an ocean general circulation model (*Resnyansky and Zelenko, 1999*). The finite difference scheme of the model source equations was generalized for the computational domain including the near pole neighborhood, which is the singularity point in spherical coordinates.

The numerical experiments have been conducted for the global multiply connected domain (22 internal closed shore contours) including the Arctic Ocean with horizontal grid resolution $\Delta\lambda=\Delta\varphi=1{,}25°$. The model bathymetry, which also determines the land-sea mask, was constructed on the basis of the WOA-98 electronic atlas. The data from this atlas were also used to specify initial three-dimensional distributions of water temperature and salinity.

The daily atmospheric forcing (wind stress, net heat and fresh water fluxes, i.e. precipitation–evaporation difference) were specified from the meteorological NCEP/NCAR reanalysis data (*Kalnay et al., 1996*) in combination with the relaxation of the computed near-surface water temperature and salinity values to specified distributions from the WOA-98 atlas assuming relaxation coefficient $c_r^{-1} = 30\ d$.

The extent of sea ice was prescribed from daily NCEP data. Dynamic impact of ice on underlying water was allowed for by 20 % reduction of the wind stress vector module exerted on the water surface accompanied by a clockwise rotation of the vector through 20°. Thermodynamic impact was simulated by equating the under ice water temperature to freezing point –1,9°C.

The model has been integrated for several years starting from the state of no motion with climatological temperature and salinity distributions.

The calculations have been reproduced many of the prominent features of large scale water mass exchange of the Arctic Ocean with adjacent basins. Among them, in particular, is such characteristic feature as submerging of West Spitsbergen current under the Arctic surface water as it flows northward (Figure 1). Similar pattern of abrupt submerging is typical of other places of inflow of the Atlantic water under the Arctic surface water.

The pronounced high amplitude short-term variations draw the attention on examination of temporal changes of the net water transport through the straits connecting the Arctic Ocean with adjacent basins. The relationships among different ranges of temporal variability obtained in model simulations (Figure 2) are generally consistent with available direct estimates. In particular, according to evidence of (*Coachman and Aagaard, 1988*), the mean inflow transport through the Bering Strait is about 0.8 *Sv* (1 $Sv = 10^6\ m^3\ s^{-1}$). This average transport is superimposed by seasonal and interannual variations with amplitude of an order 1 *Sv* and 0.2 *Sv* respectively. But even greater amplitudes are seen for short-term variations. According to (*Coachman, 1993*) they can reach 3.0 *Sv* to the North and 5.0 *Sv* to the South. Similar variability occurs in other passages, through which the Arctic Ocean communicates with neighboring basins, for instance in Fram Strait (Figure 2*b*).

Acknowledgment: This work was supported by the Russian Foundation for Basic Research grant No. 03-05-64814.

References

Coachman, L.K., 1993: On the flow field in the Chirikov Basin. *Cont. Shelf Res.*, **13**, 481-508.

Coachman, L.K. and K. Aagaard, 1988: Transports through Bering Strait: Annual and inter-annual variability. *J. Geophys. Res.*, **C93**, 15535-15539.

Kalnay, E., M. Kanamitsu, R. Kistler, et al., 1996: The NCEP/NCAR 40-Year Reanalysis Project. *Bulletin of the American Meteorological Society*, **77**, 437-471.

Resnyansky, Yu.D. and A.A. Zelenko, 1999: Effects of synoptic variations of atmospheric forcing in an ocean general circulation model: Direct and indirect manifestations. *Russian Meteorology and Hydrology*, No. 9, 42-50.

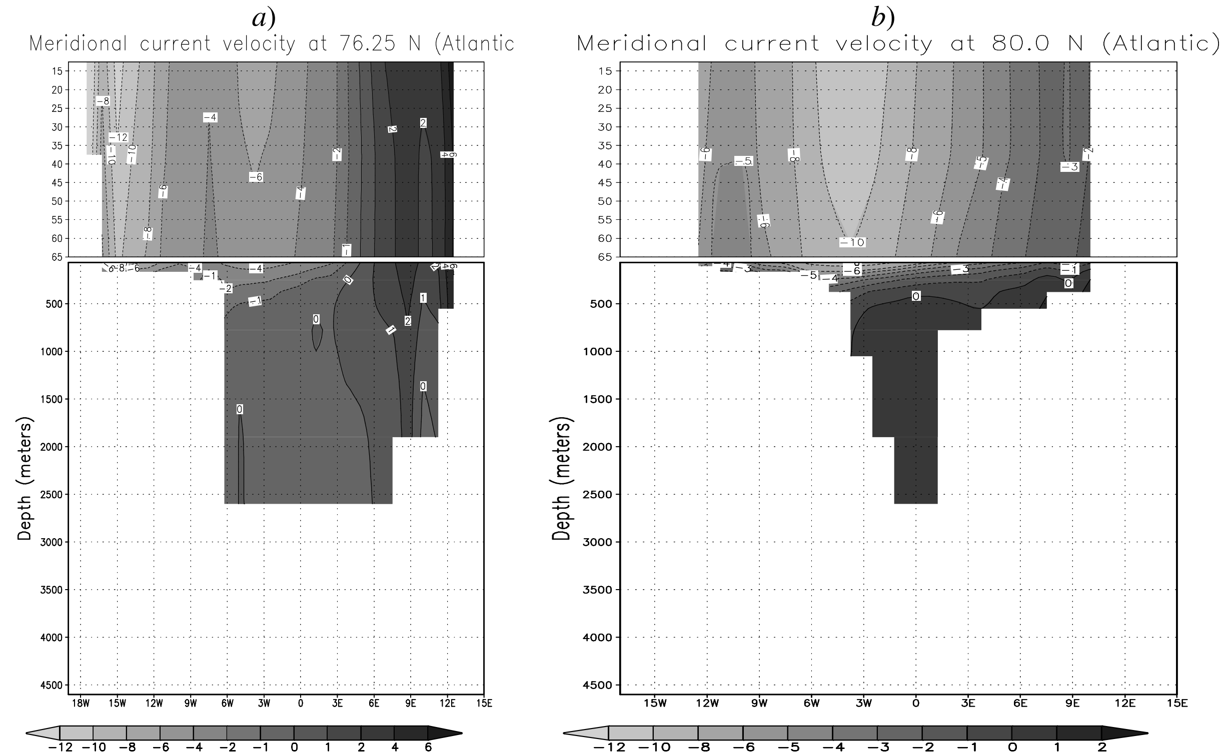

Figure 1. The distribution of the meridional current velocity component (*cm* s^{-1}) within two zonal cross-sections through the Fram Strait along latitudes 76.25° N (*a*) and 80° N (*b*).

Note: The velocity is averaged over the last (1997) year of the tree year ocean general circulation model integration on the 1.25°x1.25° grid within the computation domain involving the North Pole. The northward flow seen at 76.25° N in the surface layers off the western coast of Spitsbergen Island is transformed into the flow submerging within the layer from 500 to 2500 *m* at 80° N.

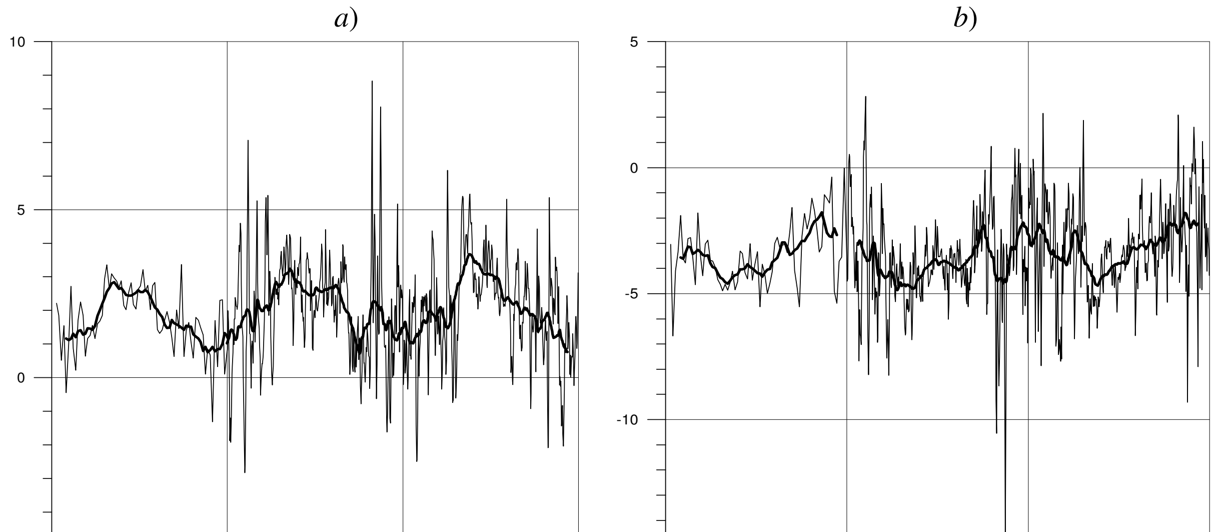

Figure 2. Temporal variations of the overall transports (*Sv*) through Bering Strait (*a*) and Fram Strait (*b*) over three years of model integration with daily atmospheric forcing derived from the NCEP/NCAR reanalysis. Positive values correspond to the northward water transport (from the Pacific to the Arctic Ocean In Bering Strait and from the Atlantic to the Arctic Ocean in Fram Strait). The bold line shows 45 days running mean.