Influence of rapid regional climate warming on the water mass formation in the Japan/East Sea.

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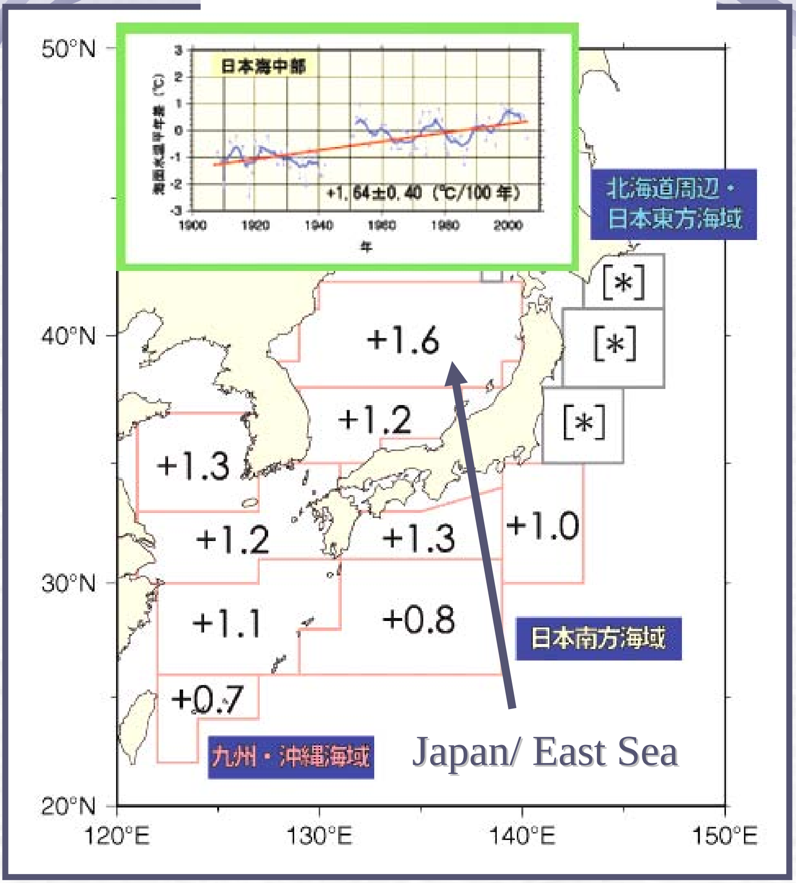
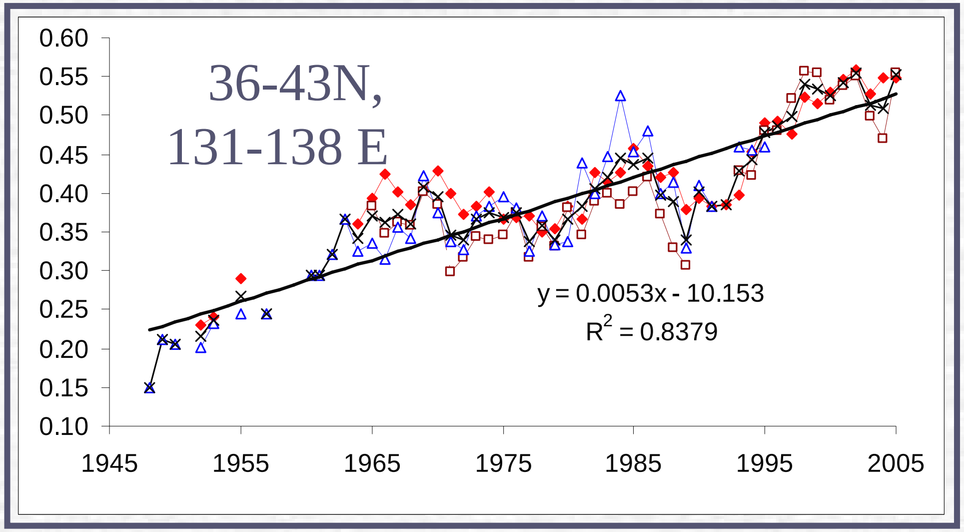
ТОИ ДВО РАН

SST ANOMALY (JMA)



Evidences of the rapid regional warming



The increase of potential temperature of the intermediate layer (500 m, Hight Salinity Intermediate Water).

The Japan/East Sea (JES) is often used as a "miniature" of the ocean to assess influences of global climate change on the marine environment. The JES is located in the region of high warming trend. Sea surface temperatures in the JES have increased as much as three times the world average over the past century, partly due to global warming. As well as effects on ecosystems (e.g. by decrease of the ice cover area), warming could reduce the ocean ability to absorb CO_2. Sea surface temperatures increase more in winter season. The wintertime circulation and water mass formation in the JES are thought to be strongly driven by surface fresh water and heat fluxes .

The goals of the work are:

- to calculate the rates of the water mass transformations/formation in the JES by the climatological fluxes of heat and fresh water

- to detect of the trend in the water mass formation in the JES

- to compare of the trend in the water mass formation with the Climate Indices: (AO) Arctic Oscillation and (SH) Siberian High

Method

- Walin (1982) and Tziperman (1986) developed an theoretical frame to analyze the annual mean water mass formation rates from heat and fresh water fluxes at the ocean’s surface.
- The method does not require a knowledge of the volume of water involved in the exchange with the atmosphere, but only of the surface properties of this water (the salinity and the temperature) and the air-sea flux data (the precipitation,the evaporation and the net heat flux).
- Air-sea fluxes at sea surface change the temperature and salinity and convert water from one density to another. If the rate of conversion varies, then water removing from some density and accumulating at others. This simple idea leads to the possibility of quantitative estimates of the formation rate of various water masses.

The vertical water mass flux at the sea surface is given by the following equation

$$F = \frac{\alpha}{C_w} H - \rho\beta(E - P)S$$

α	is the coefficient of thermal expansion of sea-water;
β	is the haline contraction coefficient;
C_w	is the heat capacity of sea water;
H	is the net heat flux;
E-P	*is* the net fresh water flux;
ρ	is the density of the surface water;
S	is the salinity of the surface water;
T	is the temperature of the surface water.

The vertical water mass flux for one year as a function of sea surface density at any area is found using the following expression:

$$F(\rho) = \int_{1\_year} dt \iint_{surface\_area} dA F \delta(\rho' - \rho)$$

The water mass that accumulates over the year between any two isopicnal ρ *and* $\rho + d\rho$ my be written as

$$M(\rho)d\rho = F(\rho + d\rho) - F(\rho)$$

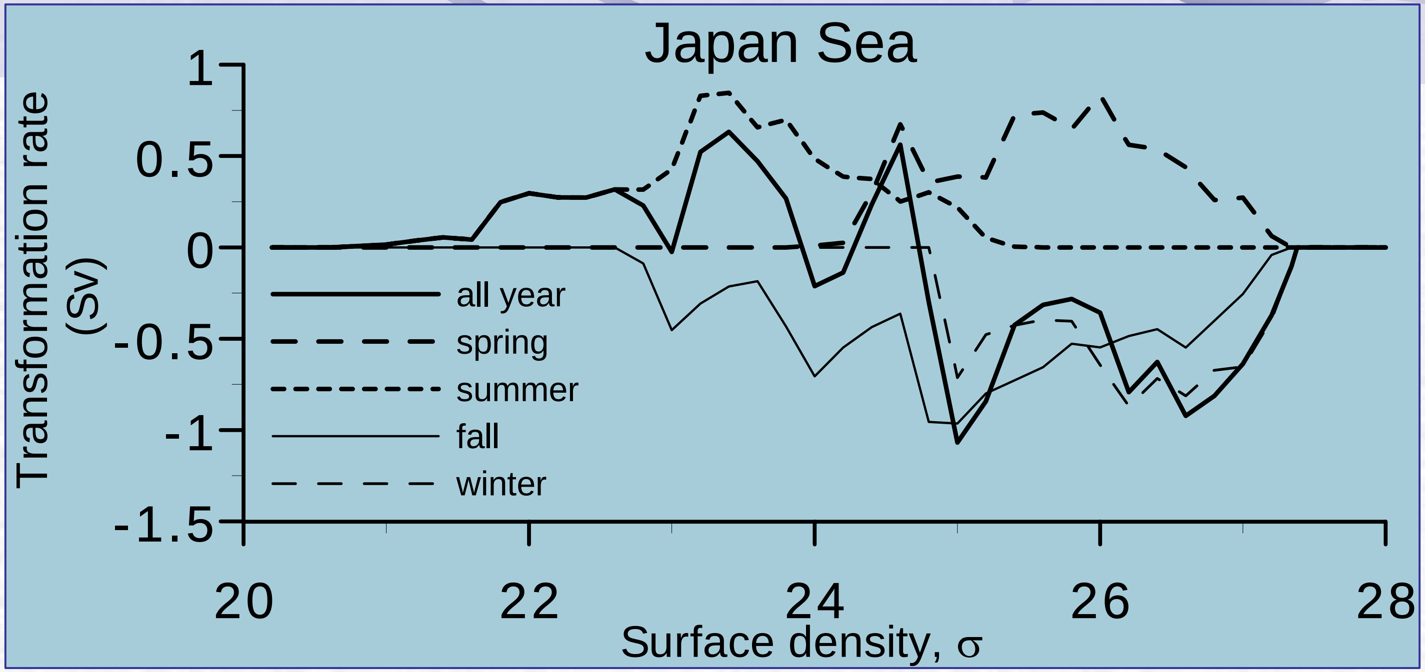
Data

In this study we used:

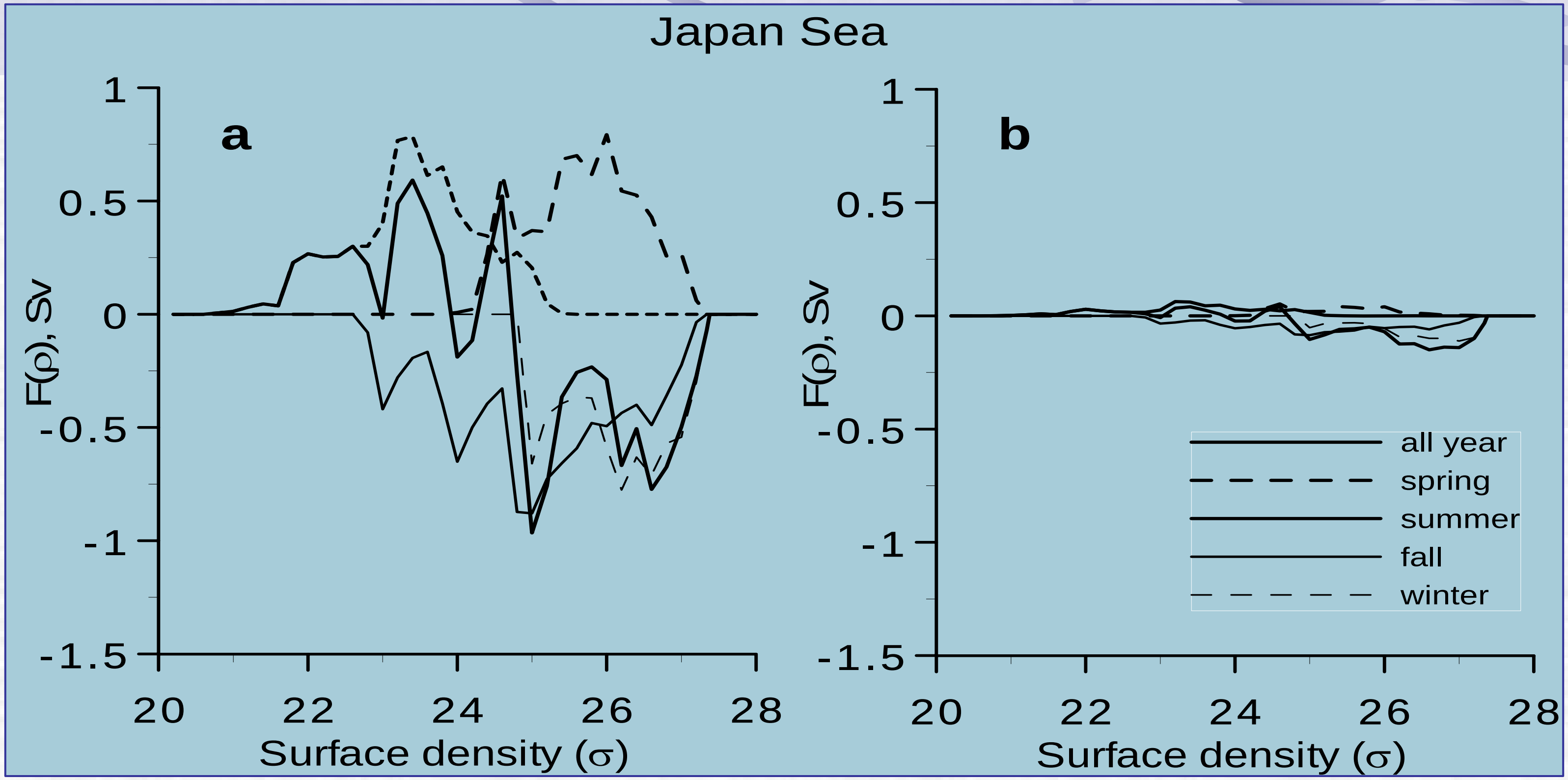
the climatological monthly averages of the heat fluxes, evaporation, precipitation from the **Southampton Oceanography Centre** dataset (Great Britain, ttp://www.soc.soton.ac.uk/JRD/MET/fluxclimatology).

the surface temperature and salinity from the **National Oceanographic Data Center** (USA, http://www.nodc.noaa.gov, WOA 2001).

the **NCEP/NCAR reanalysis** data from 1948 to 2002.

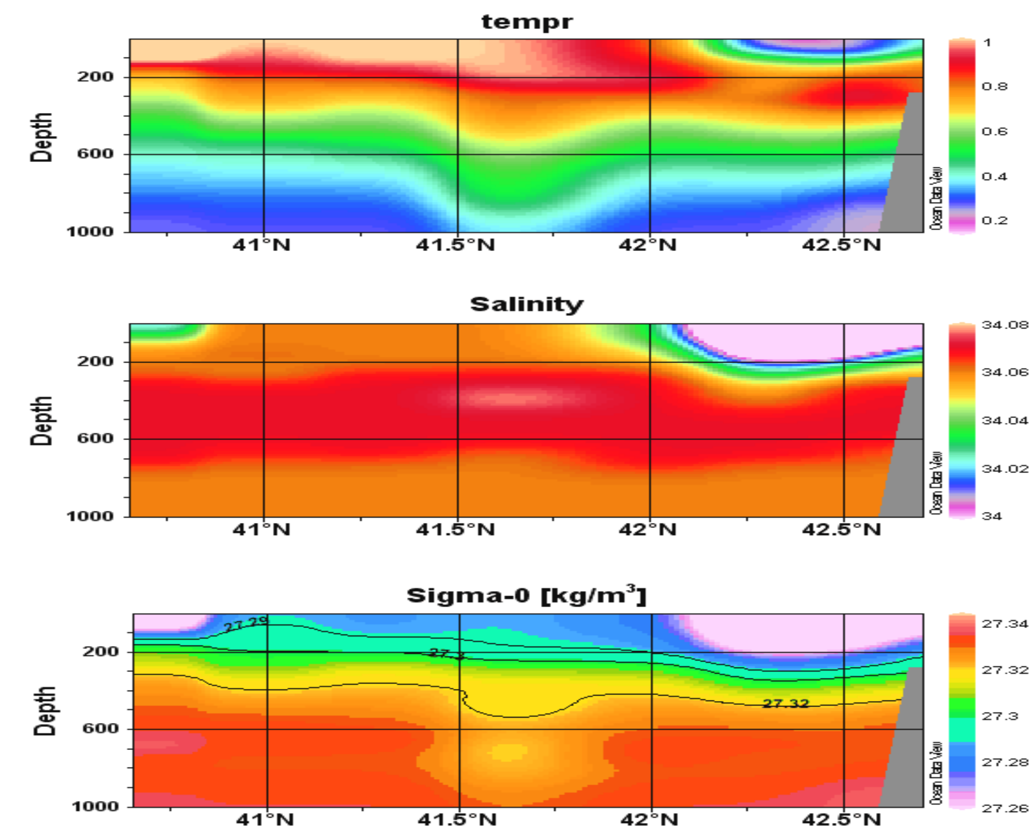


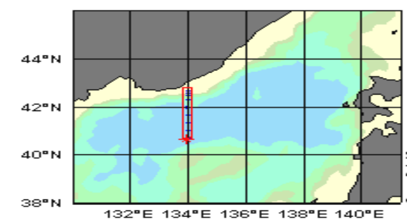
The rate of the water mass transformation, calculated for the JES. The thick line describes the cross-isopicnal mass flux for a full climatological year. The positive slope of the curve F(ρ) indicates water mass formation at the density ρ, whereas a negative slope indicates a net loss of water mass owing the air-sea fluxes. The air-sea fluxes transform an average of 3.3 Sv of surface water to greater (1.7 Sv) and smaller (1.6 Sv) densities. During one year from surface water forms of 0.2 Sv of the HSIW (>27.3σ) .



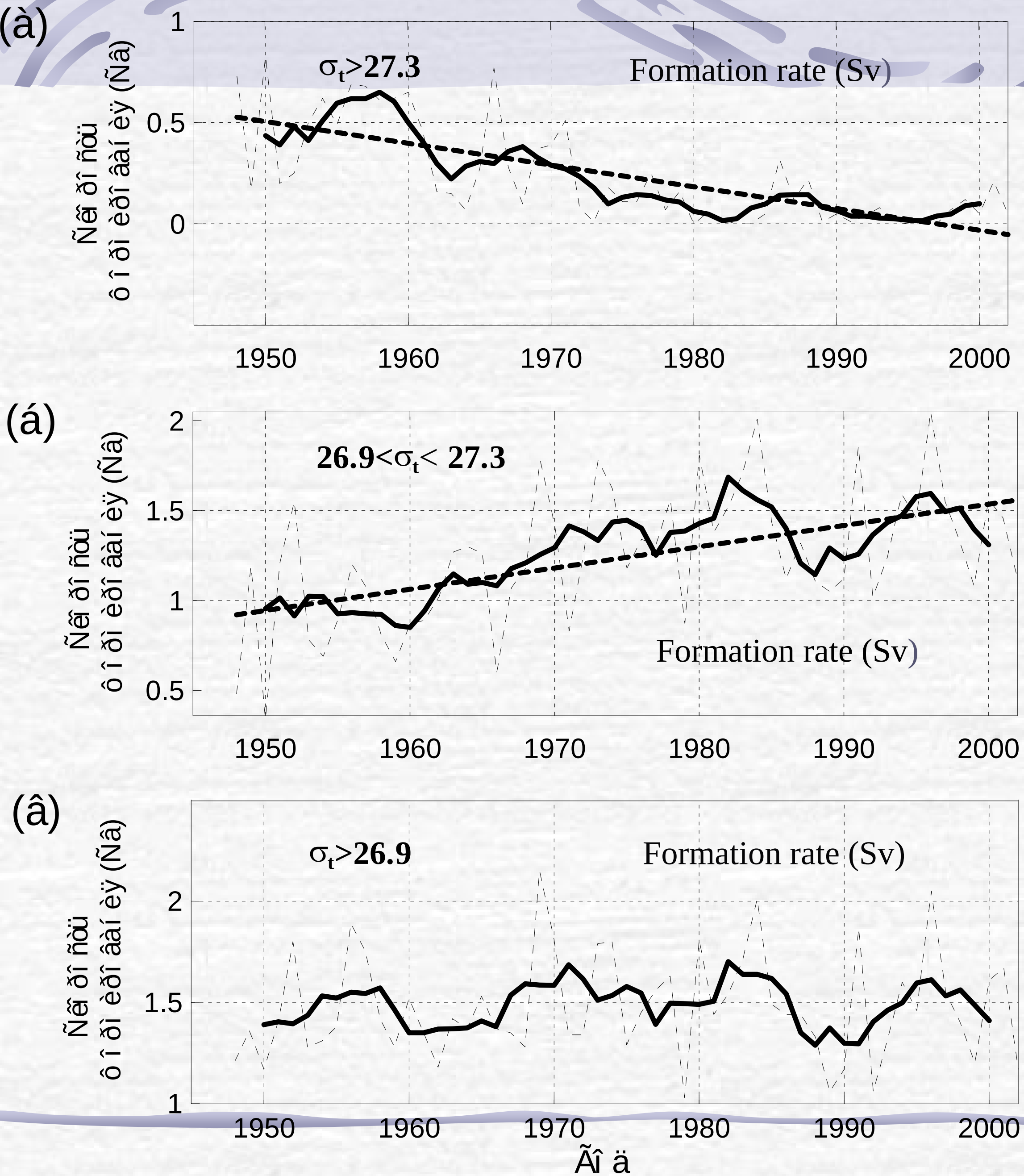
The rate of the water mass transformation, calculated only the contribution of air-sea fluxes (a) and the contribution of evaporation and precipitation (b). The strongest component of the annual average air-sea forcing in the JES seems to be the heat flux (0.75 Sv). The freshwater flux, which results in a net evaporation, systematically enhances the water mass transformation towards dense and salty water masses (0.1-0.15 Sv).

Vertical section of temperature, salinity and potential density along 134 N (winter 2003)



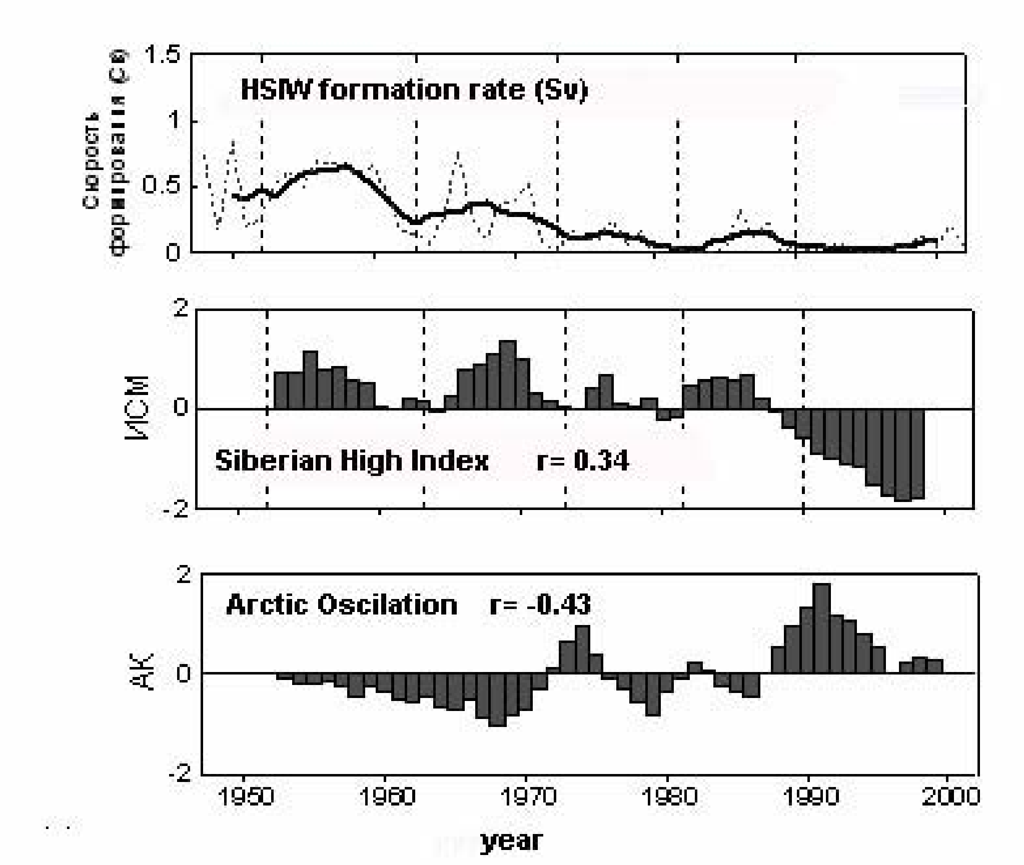


The upper panel shows winter subarctic surface mixed layer (mean depth about 200 m, σ_θ <27,3). Middle –Hight Salinity Intermediate Water (HSIW,200-500 m, σ_θ > 27,3)



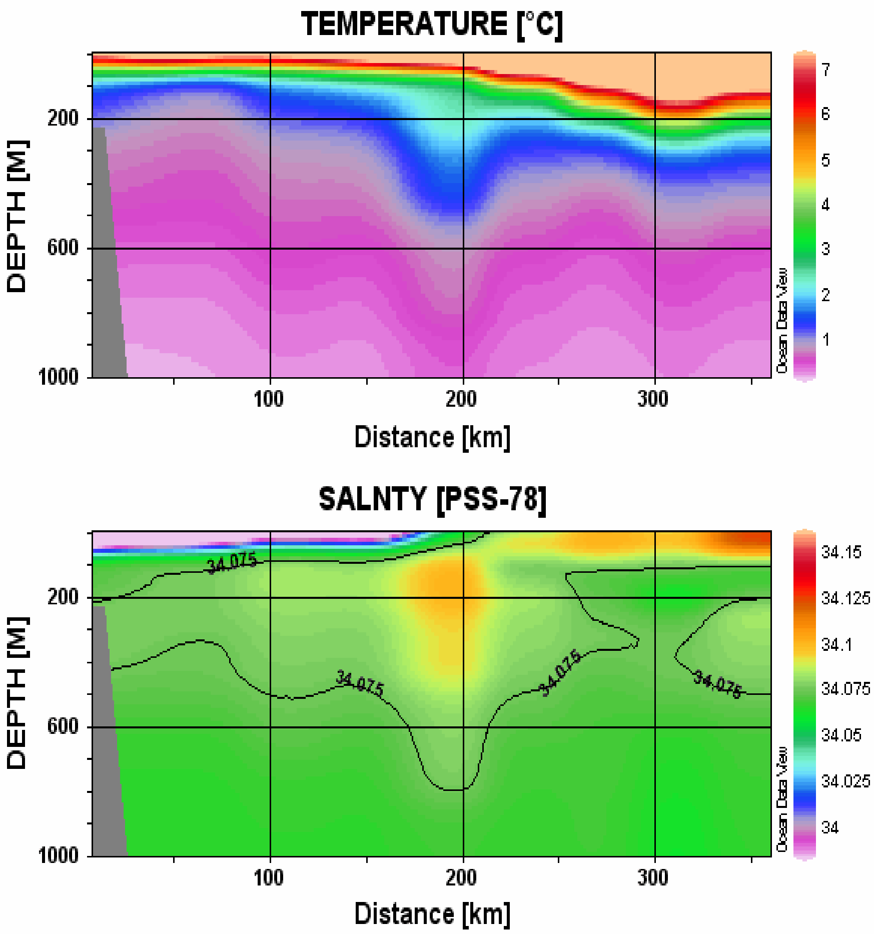
The longer-term variability in the intermediate water mass formation in the Japan / East Sea

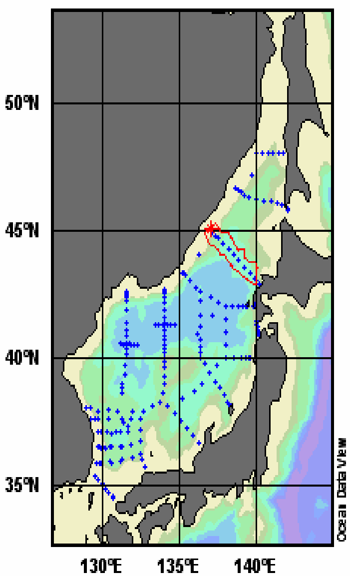
The NCEP/NCAR reanalysis data are used to estimate the rate water mass transformation in the JES from 1948 to 2002. The amount of surface water that sinks and forms the intermediate mass are defined. We found that the formation rate of water with density of the HSIW ($\sigma_\theta > 27,3$) decreased (-0.11 Sv/decade) and the formation rate of water with density 26.9–27.3σ_θ increased (0.12 Sv/decade). Some of this low- density water sinks to form the JES Intermediate Water. The total formation rate of intermediate water is not change.



Climate indexes are used to represent the essential elements of climate. The formation of the HSIW is primarily influenced by the (AO) Arctic Oscillation (negative correlation, r = -0.43) and secondary influenced by the (SH) Siberian High (r =0.34). The winter AO influences directly on surface air temperature over the JES region. The SH shows more direct and significant influences on winter northerly monsoon winds. The decreasing of the formation rate of more dense water during the last decade may be due to the combined effects of the winter sea surface warming (positive index phase of AO) and weakness of the East Asian Winter Monsoon (negative index phase of SH).

The impact of subgrid mesoscale eddies on the HSIW formation





Significant reduction of the formation rate of water with density of HSIW does not mean that process has stopped."Proto" HSIW have been found in the core of the anticyclonic eddy in the Norteastern part of JES (Talley et al, 2006)

Summary

The water mass transformation/formation reflects only the amount of dense water formed by sea-air fluxes. Because salinity variations are very small and time dependence throughout the water column is large we can define in this study only HSIW which characterized by vertical salinity maximum between 200-500 m. Some of this water remain near surface, and some of this water sink to form HSIW.A critical point for the calculation on water mass formation rates is the quality of the flux data.