North Pacific Marine Science Organization
PICES 2013 Annual Meeting
Communicating Forecast, Uncertainty and Consequences of Ecosystem Change
October, 11 - 20, 2013 Nanaimo BC, Canada

# Interdecadal variability of circulation in the northern Japan/East Sea based on numerical simulations

Dmitry V. Stepanov[1], Victoriia I. Stepanova[1] and Nikolay A. Diansky[2]
*[1]Laboratory of Geophysical Hydrodynamics, POI FEB RAS, step-nov@poi.dvo.ru*
*[2]Institute of Numerical Mathematics of the RAS*

# Motivation

- The ocean and atmosphere interaction.
- Marginal seas and circulation variability in the Japan/East Sea.
- The Japan/East Sea temperature variability based on oceanographic observations.
- Circulation variability in the intermediate and abyssal layers of the Japan/East Sea is still poorly understood.
- Decision of this problem is complicated by sporadic and short time current measurements in these layers. So, numerical modelling is one of the approaches to decision of this problem.

# Numerical Mathematics Institute Ocean Model (INMOM)

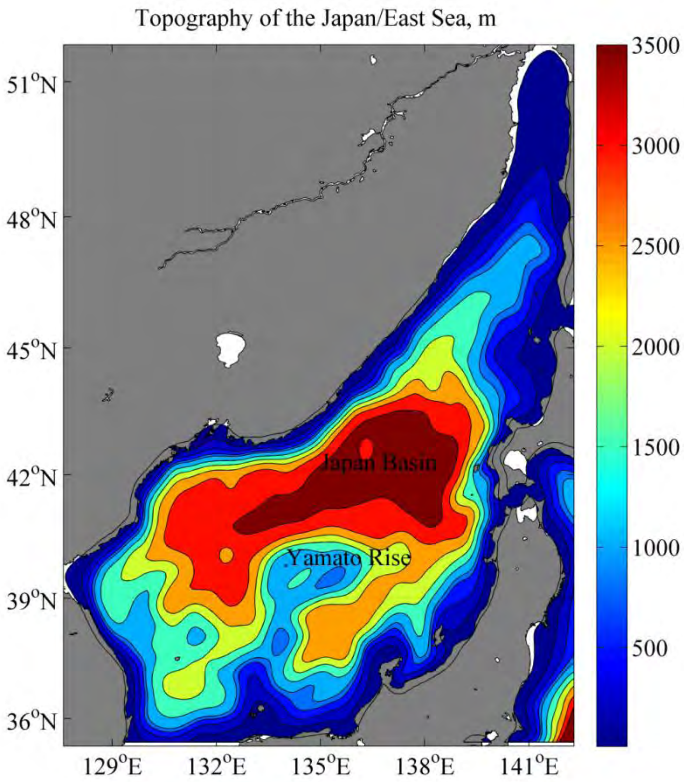
INMOM is a three-dimensional, free surface, sigma coordinate circulation model. The hydrostatic and Boussinesq approximations are used by the model. The model variables are the three velocity components, potential temperature, and salinity as well as free surface elevation.

$$\sigma = \frac{z-\zeta}{H-\zeta},$$

where $H-\zeta$ is the full depth, $\zeta$ is the free surface elevation and z is the vertical coordinate.

The model uses spatial approximations on a staggered C-grid. The splitting method allows to implement efficient implicit time-integration schemes for the transport and diffusion equations (the Crank-Nicholson approximation is used for transport processes, and an implicit scheme is used for calculating diffusion and viscosity).

# INMOM Parameters, Initial Fields and Forcing




Horizontal resolution ranges from 8.97 to 6.79 km in longitude and constant 8.97 km in latitude. Vertical resolution is 15 sigma-levels. The coefficients of horizontal viscosity and diffusivity are taken as $2\times10^2$ $m^2/s$ and to $4\times10^2$ $m^2/s$, respectively. The coefficients of vertical viscosity and diffusivity are calculated by the Monin-Obukhov parameterization with background values varying from $5\times10^{-6}$ $m^2/s$ to $5\times10^{-3}$ $m^2/s$ and $1\times10^{-4}$ $m^2/s$ to $7\times10^{-3}$ $m^2/s$ , respectively. Time step is 180 second.

**Open boundary conditions**

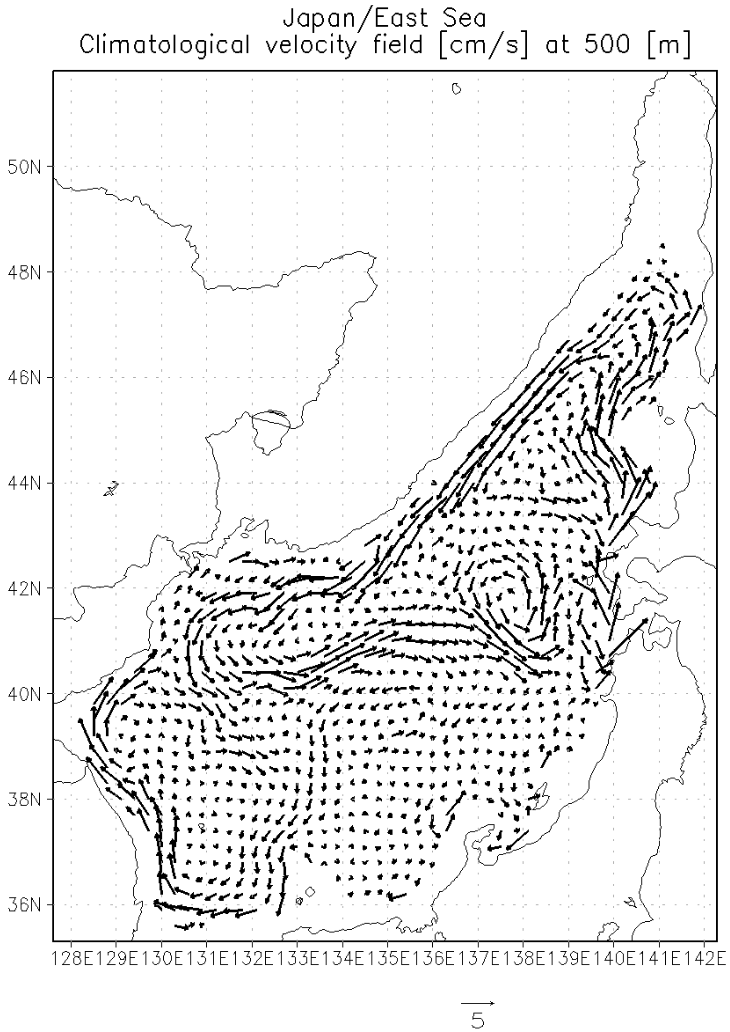
“Nudging” condition is taken for temperature and salinity at the open boundaries (straits). The relaxation time is taken about 5 days.

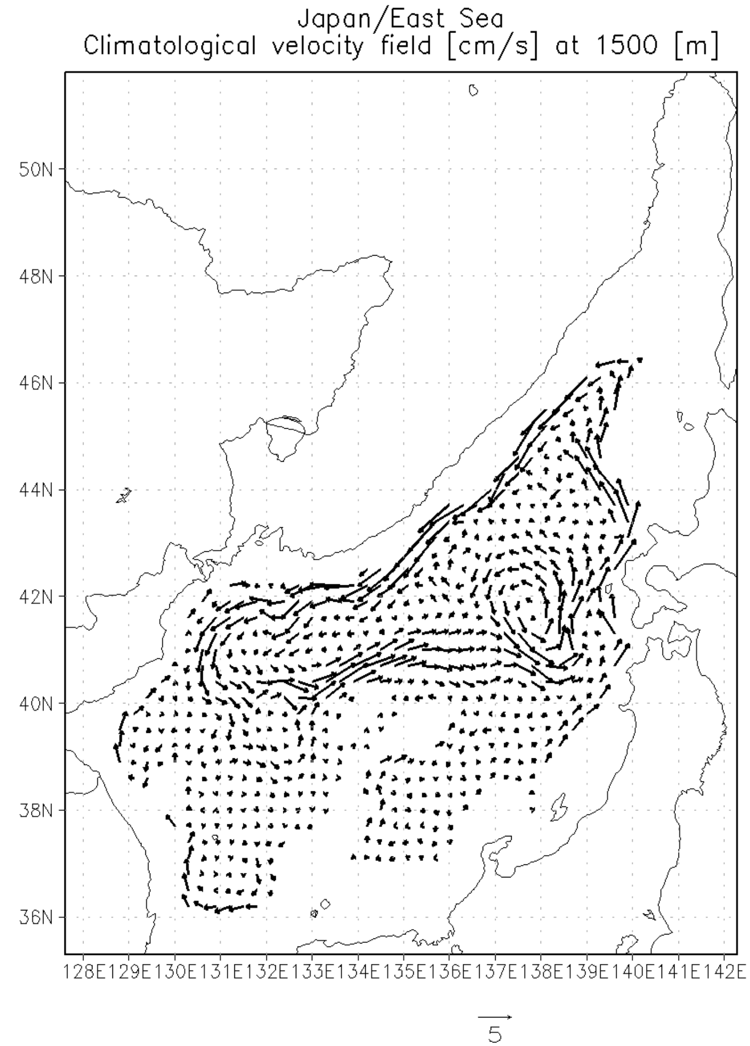
**Initial Temperature and Salinity World Ocean Database 1999.**

**Atmosphere forcing**

Database CORE (forcing for Common Ocean-ice Reference Experiments) 1958-2006 contains the following fields on a horizontal grid of 192 longitude points and 94 latitude points; monthly varying precipitation (12 time steps); daily varying shortwave and longwave (365 time steps–no diurnal cycle and no leap years); six-hourly varying 10m temperature, humidity, zonal velocity, meridional velocity, sea level pressure (4 × 365 × 43 time steps–no leap years for the interannual data) and the Normal-year forcing. Full time integration is 54 years.

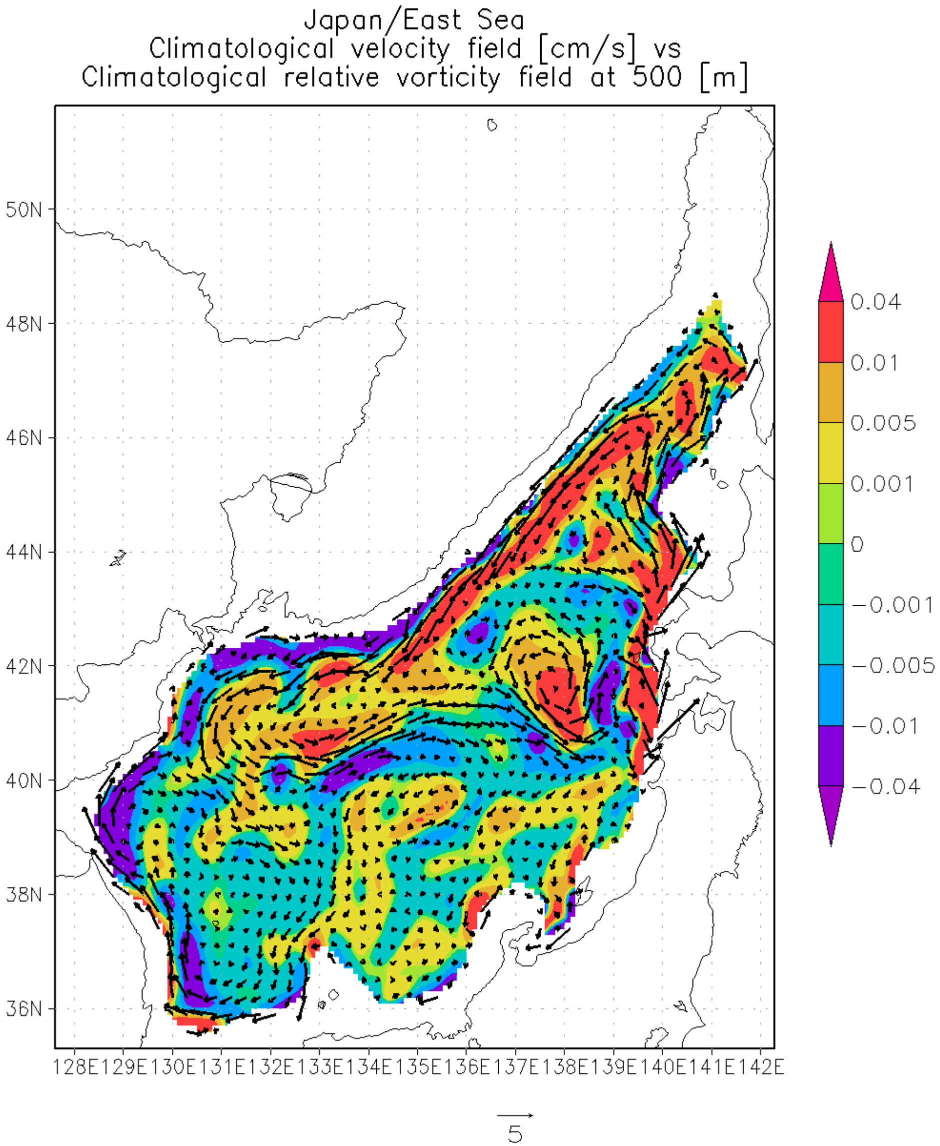
# The Japan/East Sea circulation in the intermediate and abyssal layers




Climatological (the mean from 1958 to 2006) velocity fields

# Relative vorticity and circulation




$$\omega = \left( \frac{1}{\cos\varphi} \frac{\partial v}{\partial \lambda} - \frac{\partial u}{\partial \varphi} \right) \Big/ R f_0 ,$$

where $\lambda$ is the longitude, $\varphi$ is the latitude, R is the Earth's radius and $f_0$ is the Coriolis parameter (40N).

Mean 2D relative vorticity

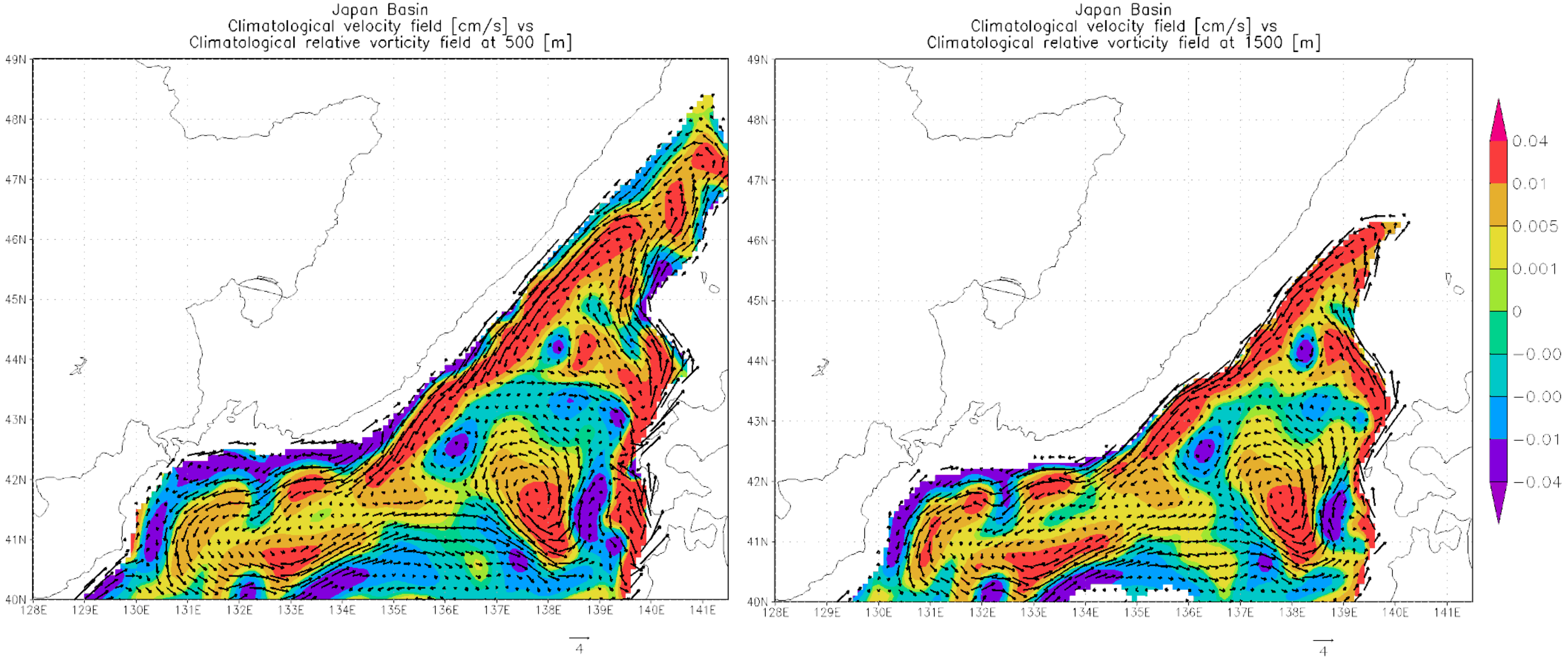
$$\bar{\omega} = \frac{1}{S_D} \iint_D \omega \cos\varphi \; d\lambda \; d\varphi \;,$$

$S_D$ is the area of region D

$$\bar{\omega} = \frac{1}{S_D f_0} \Gamma, \;\; \Gamma = \oint_{\bar{D}} \vec{v} \cdot d\vec{l}$$

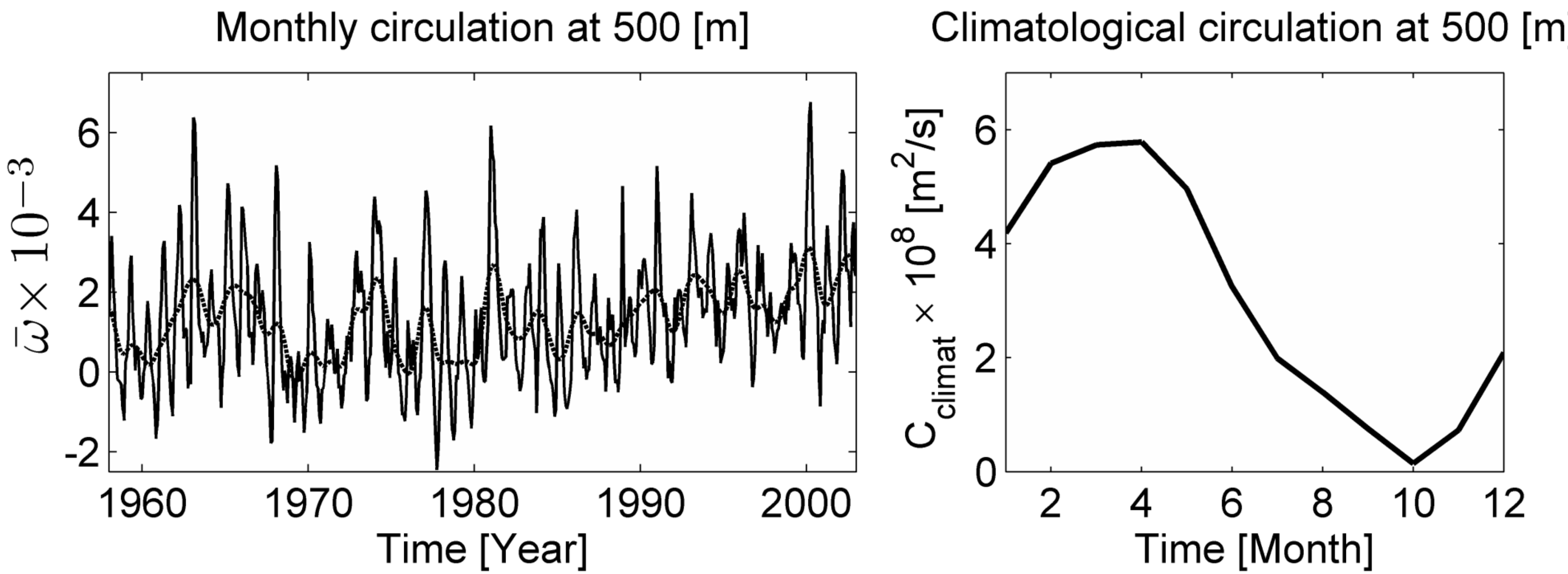
Γ is the circulation

# Circulation and relative vorticity in the norther part of the Japan/East Sea



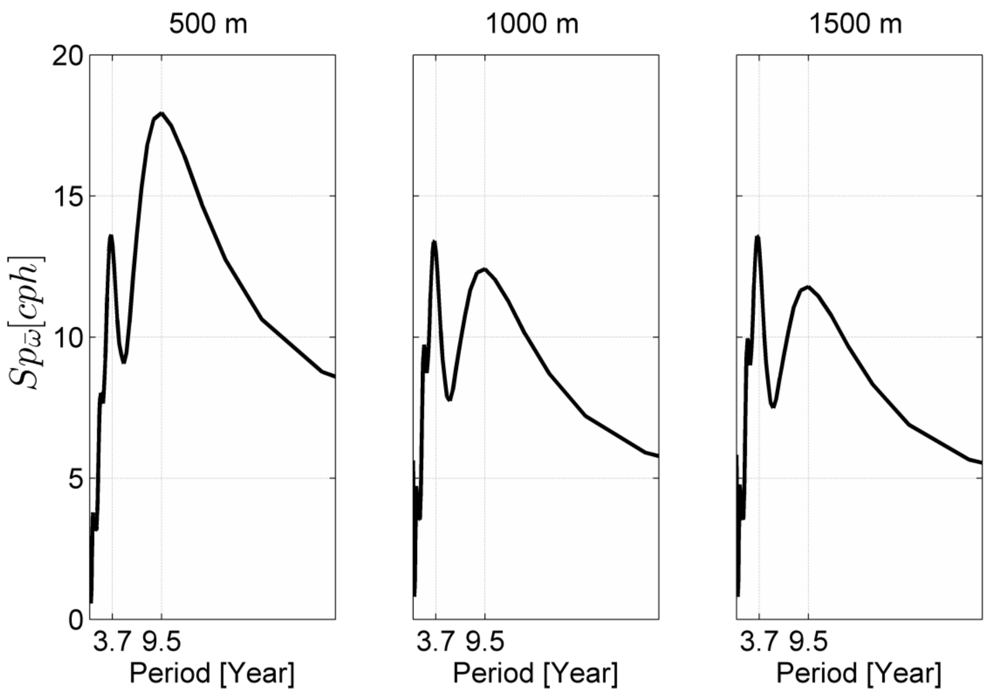

Climatological relative vorticity distribution is not uniform; there are region of positive relative vorticity dominating in the northern part of the Japan/East Sea and some regions of negative relative vorticity characterizing the mesoscale dynamics.

# Circulation variability in the northern part of the Japan/East Sea




Climatological mean 2D relative vorticity (circulation) remains cyclonic (positive) within a year with a maximum at the spring season and a minimum at the autumn season. The mean 2D relative vorticity (circulation) variability is characterized by interannual to interdecadal oscillations.

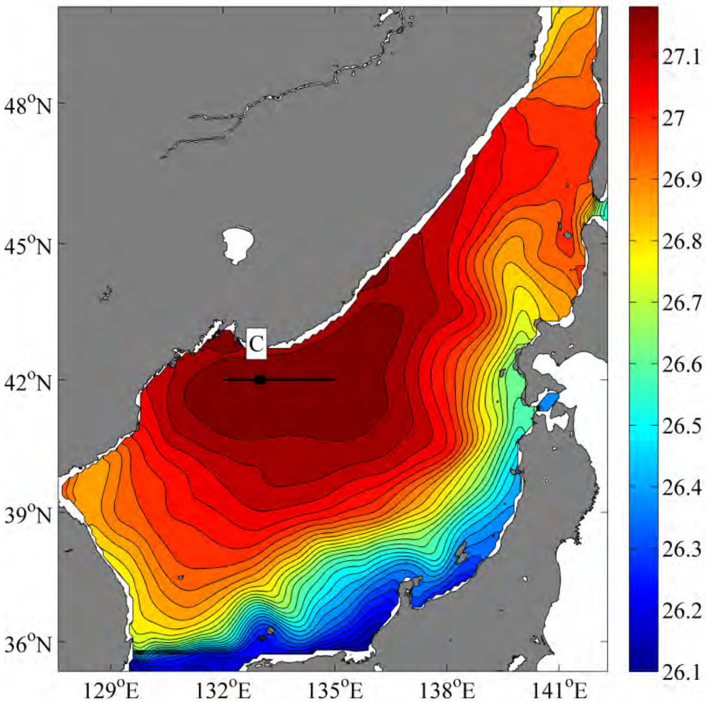
# Low-frequency variability of the circulation in the Japan Basin

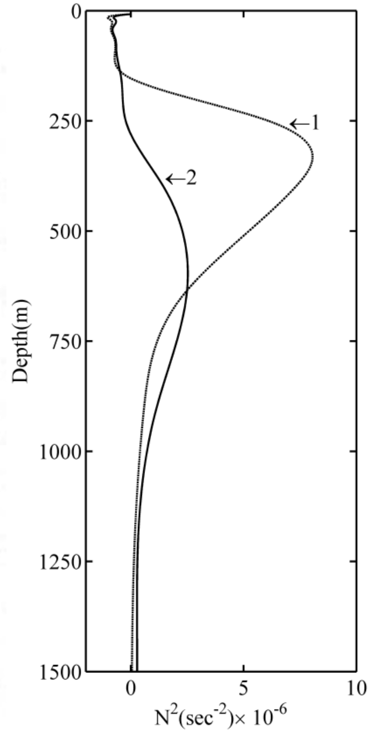


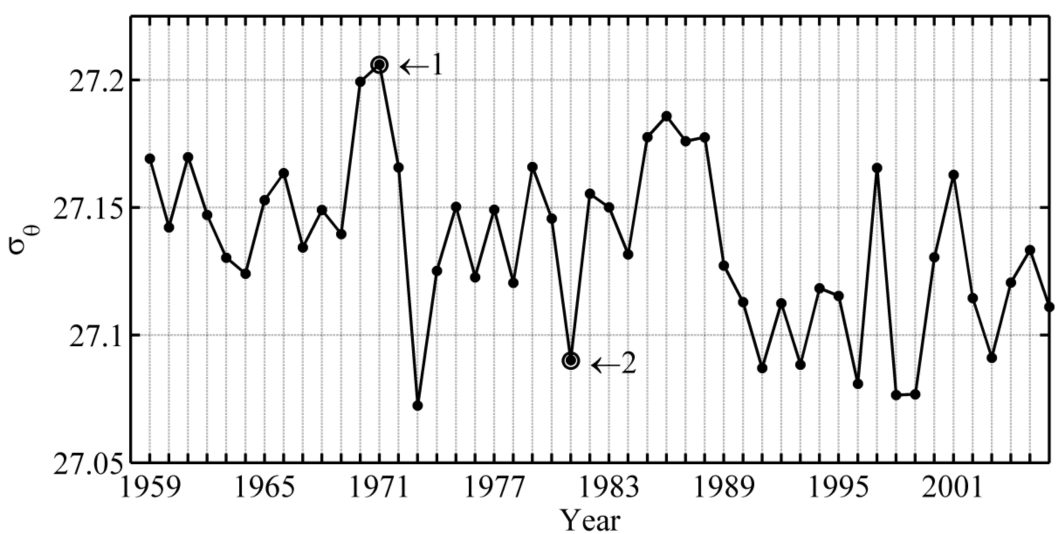

The spectrum of circulation variability is dominated by periods of 3.7 and about 10 years, which agree with the temperature variability based on observations.

We suppose that the oscillation with period of 3.7 years is determined by the Japan Basin geographical features and the decadal variability is likely caused by the winter cooling.

# Winter cooling and stratification

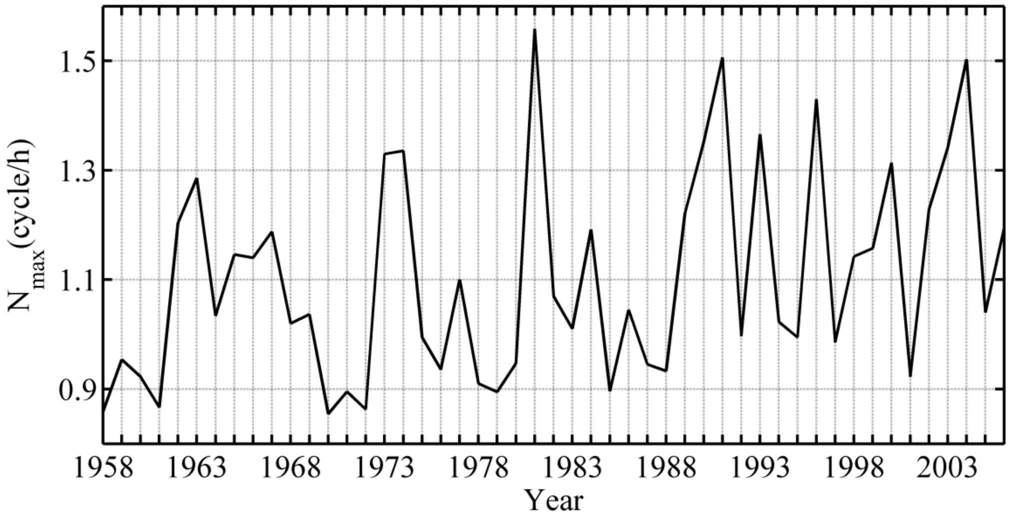


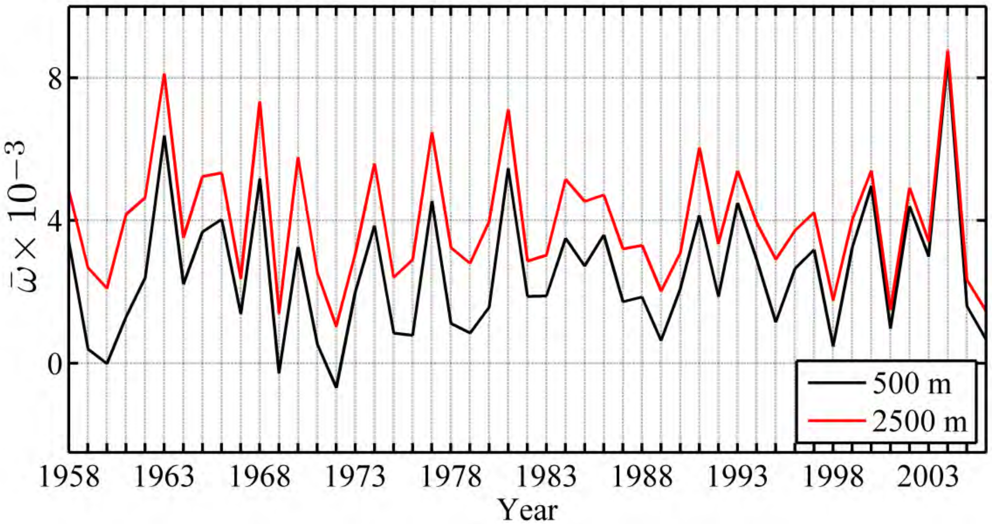




Variability of the average potential density (APD) in the box D (from 42N; 132E to 42N; 135E and from sea surface to 400 meters) characterizing intensity of the winter cooling shows decadal variability. Years with positive anomaly of the APD are associated with ‘cold’ years and years with negative anomaly are associated with ‘warm’ years. In during ‘cold’ years we found the reconstruction of density vertical structure associated with deepening of the pycnocline, which results to weaken of circulation, as opposed to ‘warm’ years.

# Connection between stratification and circulation




This finding is confirmed by direct relation between variability of the buoyancy frequency maximum (upper panel) and the circulation at the intermediate and abyssal layers (lower panel).

So, an increase in winter cooling resulting to stratification reconstruction can be reason of weakened circulation at the intermediate layer in the northern part of the Japan/East Sea on the decadal time scale.

# Conclusions

- By making use of numerical model INMOM, an analysis of circulation variability in the Japan/East Sea is presented for the second half of the 20th century. The climatological circulation at the intermediate layer and abyssal layer is reproduced.
- We found that the climatological circulation structure in the intermediate layer is dipole with the cyclonic circulation in the northern part and anticyclonic in the southern part of the Japan/East Sea. In the abyssal layer the cyclonic circulation dominates in the sea.
- It was found that the climatological circulation in the Japan Basin is cyclonic and it intensifies in winter and decays in autumn. Spectrum of the variability circulation in the Japan Basin is dominated by periods of about 4 and 10 years.
- We reveled that the change of the winter cooling conditions can be reason of the circulation decadal variability at the intermediate and abyssal layers in the Japan/East Sea. Variability circulation with period of about 4 year is associated with inertial oscillation in the Japan Basin.