North Pacific Marine Science Organization
PICES 2015 Annual Meeting
October, 14 – 25, 2015 Qingdao, China

Effects of atmospheric forcing on circulation variability in the northern Japan/East Sea in 1948 to 2010

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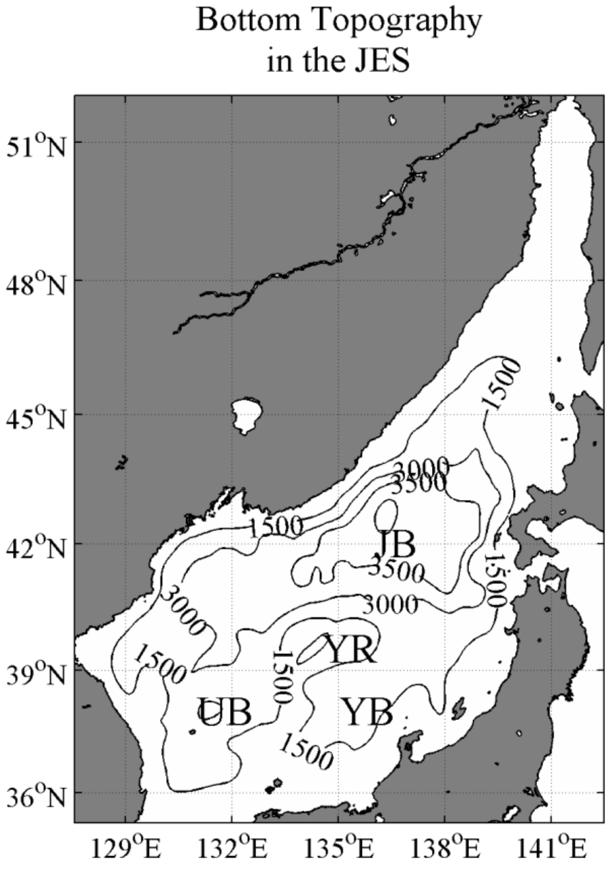
Motivation

- The Japan/East Sea (JES) is one of the marginal seas in the North Pacific
- The JES circulation and its variability are very important problems in the regional climate modelling.
- The JES is connected by shallow and narrow straits to the North Pacific, East China Sea and Okhotsk Sea. So, we face the problem of the separating of the atmospheric impact from the strait influence on the JES circulation and its variability.

Outline

1. Model configuration description
2. Verification and validation of the model configuration
3. Cyclonic gyre in the JES and its interannual and decadal variability
4. Relationships between relative vorticity and wind stress curl anomalies, 1948 to 2009
5. Relationships between buoyancy frequency and sensible heat fluxes anomalies in winter, 1948 to 2009
6. Conclusions

Model configuration



INMOM is a three-dimensional, free surface, terrain-following 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. The INMOM includes the sea-ice model.

Model Parameters

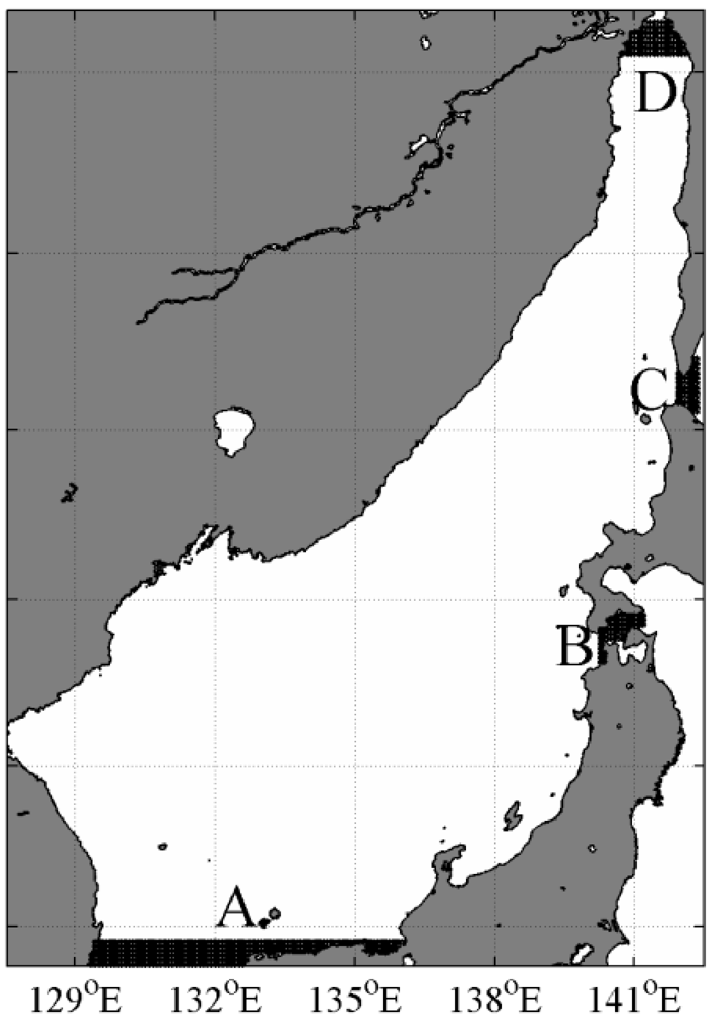
The horizontal resolution is $1/12^0$ both in zonal and meridional directions. There are 30 sigma-levels in the vertical direction. The horizontal viscosity and diffusivity coefficients are 2×10^2 m^2/s and 4×10^2 m^2/s, respectively. The vertical mixing is parameterized according to the Kochergin parametrization with background value for viscosity of 5×10^{-6} m^2/s diffusion of 10^{-4} m^2/s. Convective mixing is parameterized by enhanced vertical viscosity and diffusivity. Time step is 180 second. Initial Temperature and Salinity were extracted from WOA 2001.

Atmospheric forcing parameters

Atmospheric forcing is extracted from a CORE (Common Ocean-ice Reference Experiments) dataset. The spatial resolution of the data is longitudinally constant at 1.875 and latitudinally variable, from 1.905 at the equator to 1.887 near the poles. The data were collected from 1948 to 2009 and included the following atmospheric parameters: the air temperature and humidity, wind velocity field at a height of 10 m, precipitation, atmospheric pressure at the sea-surface 6 h, and shortwave and longwave radiation daily, as well as climatological runoff.

Model configuration
Boundary Conditions

Restoring Conditions



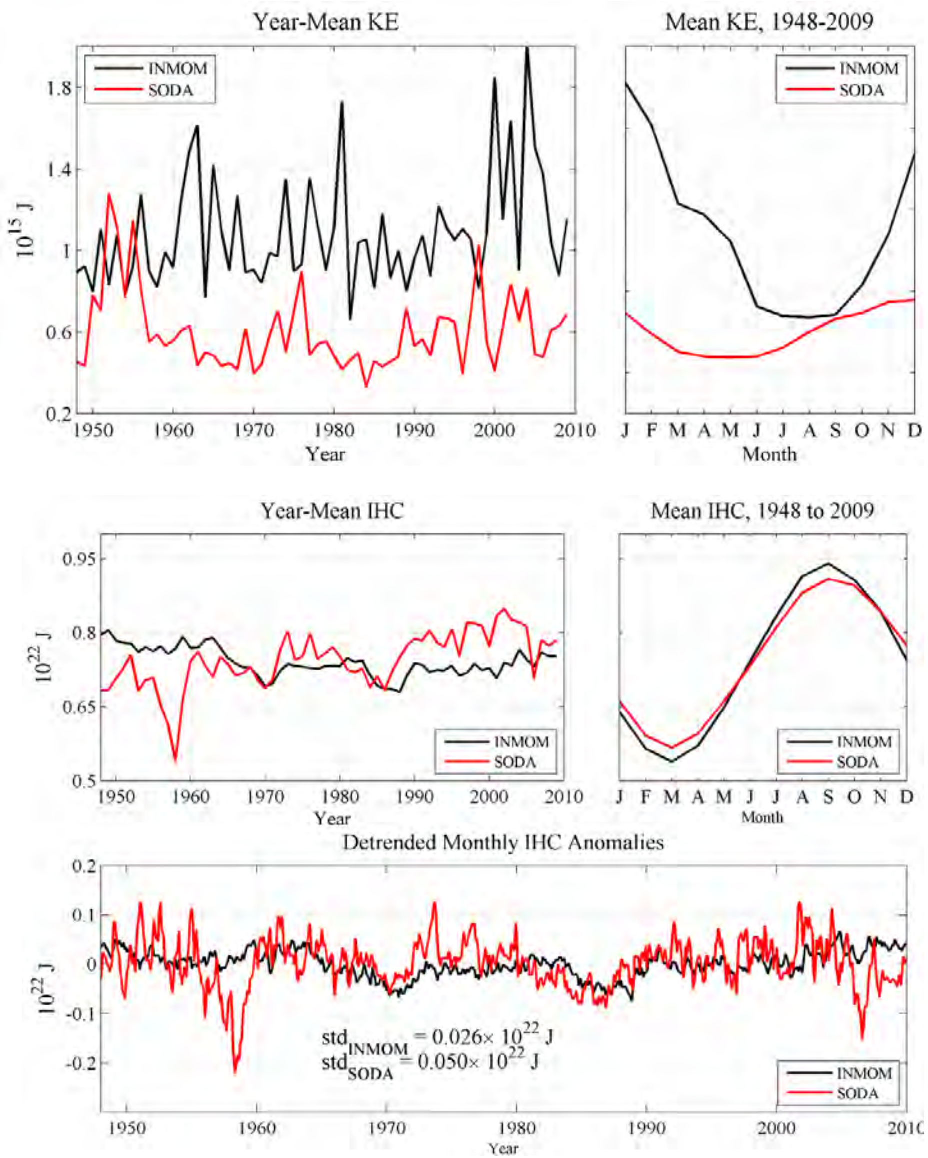
Sea surface

To calculate the heat and salinity fluxes as well as wind stress at the sea surface, we employ the bulk formulas. The potential temperature and salinity are nudged to climatological values within the sub-surface layer with depth of 50 m. The relaxation time is about 60 days both potential temperature and salinity. As the initial fields we use the temperature and salinity extracted from the World Ocean Atlas 2001.

Boundary conditions (A,B,C,D)

In the neighborhood of the each open boundary we generate the arrays of potential temperature and salinity from the sea surface to bottom. During the numerical simulations, potential temperature and salinity of the arrays are restored to climatological values with the relaxation time of about 1 day. So, we generate density currents near the each strait of the JES.

An Assessment of the Kinetic Energy and Integrated Heat Content of the simulated JES circulation, 1948-2009



Kinetic Energy of the JES circulation

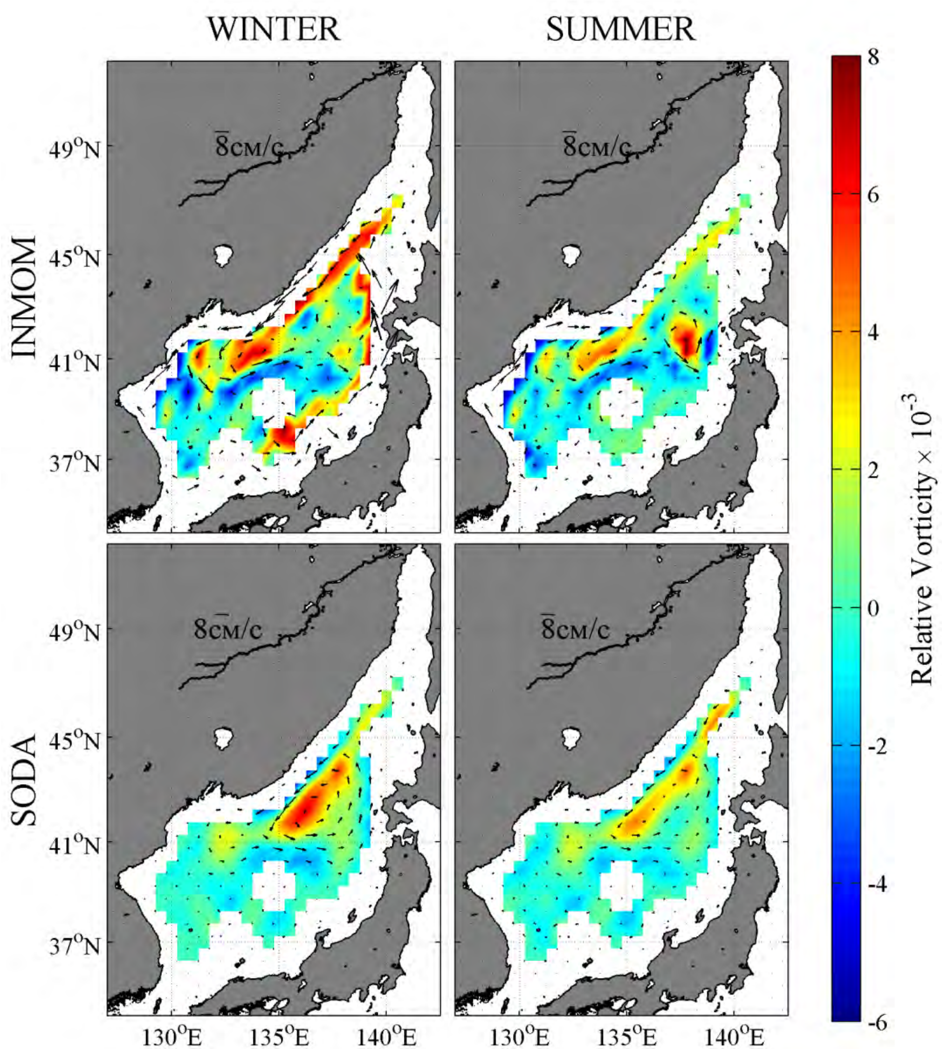
$$KE = \iiint_V \rho \frac{u^2 + v^2}{2} dV$$

Integrated Heat Content of the JES

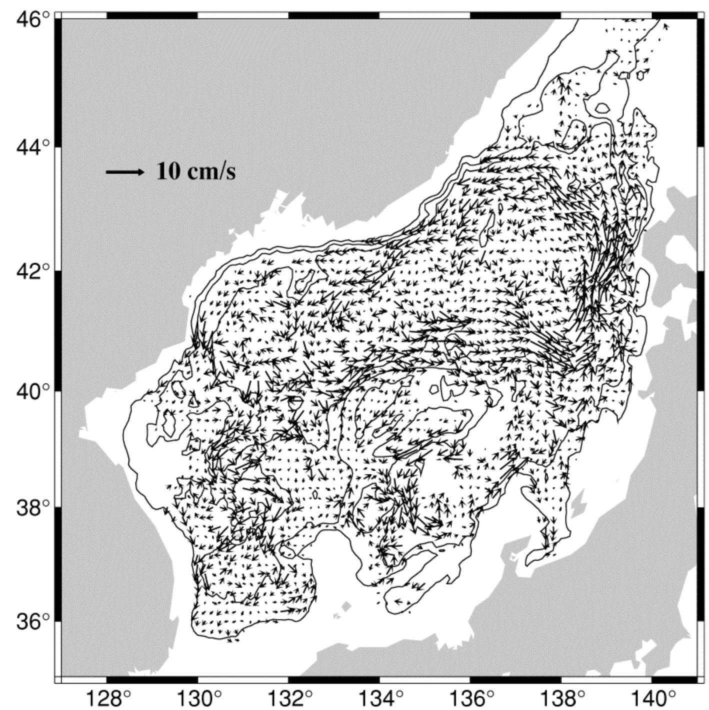
$$HTC = \iiint_V \bar{\rho}(T,S,0) c_p(T,S,0) T(x,y,z) dV$$

- Non-trends in the simulated KE and IHC time series and small (<50%) STD of the KE and IHC anomalies;
- Close similarity between the IHC of the simulated circulation and IHC from the SODA reanalysis.
- The simulated circulation in the JES is characterized by a quasi-stable state from 1948 to 2009.

Climatological velocity and relative vorticity fields, 1948 to 2009. Intermediate layer (800-1500 m)



The horizontal resolution is 1/2° degree

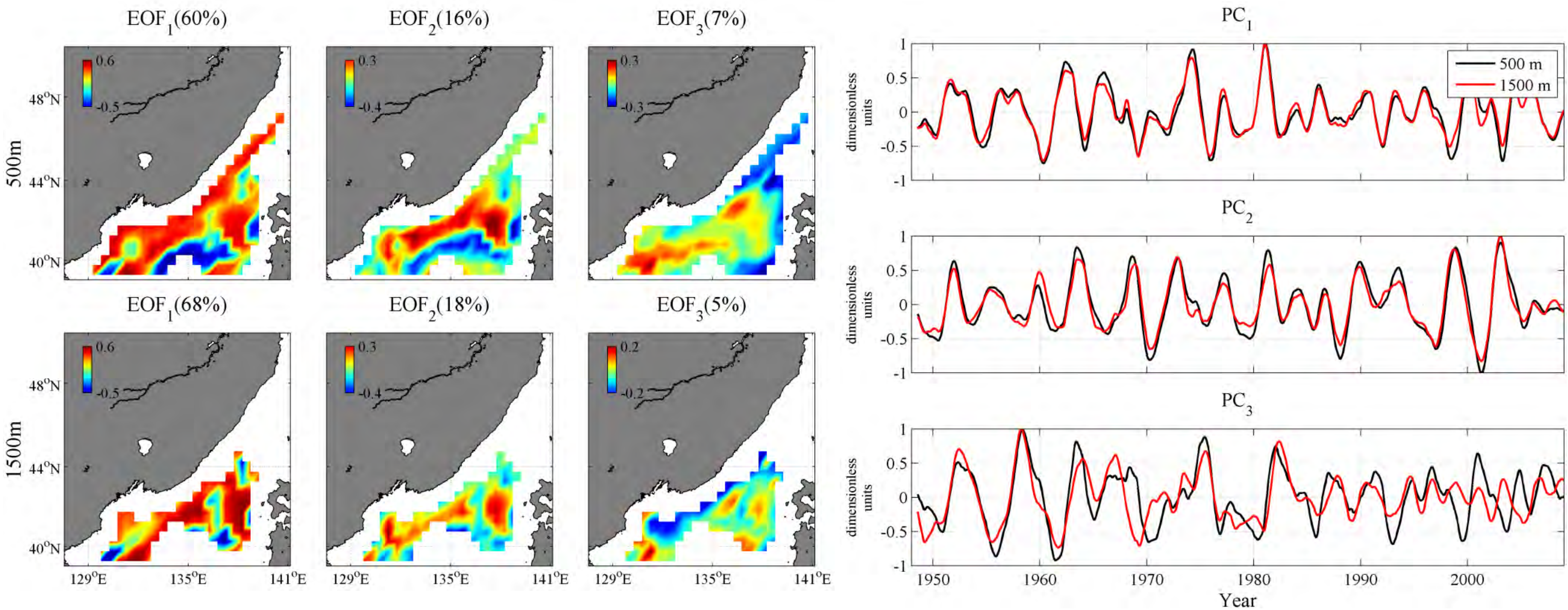


(Y.J. Choi , J.-H. Yoon J. Oceanogr. 2010, 1/6° degree, 800 dbar)

$$\omega = \frac{1}{\cos\varphi}\left(\frac{\partial v}{\partial \lambda} - \frac{\partial\left(u\cos\phi\right)}{\partial \varphi}\right)\Big/ Rf_0\,,$$

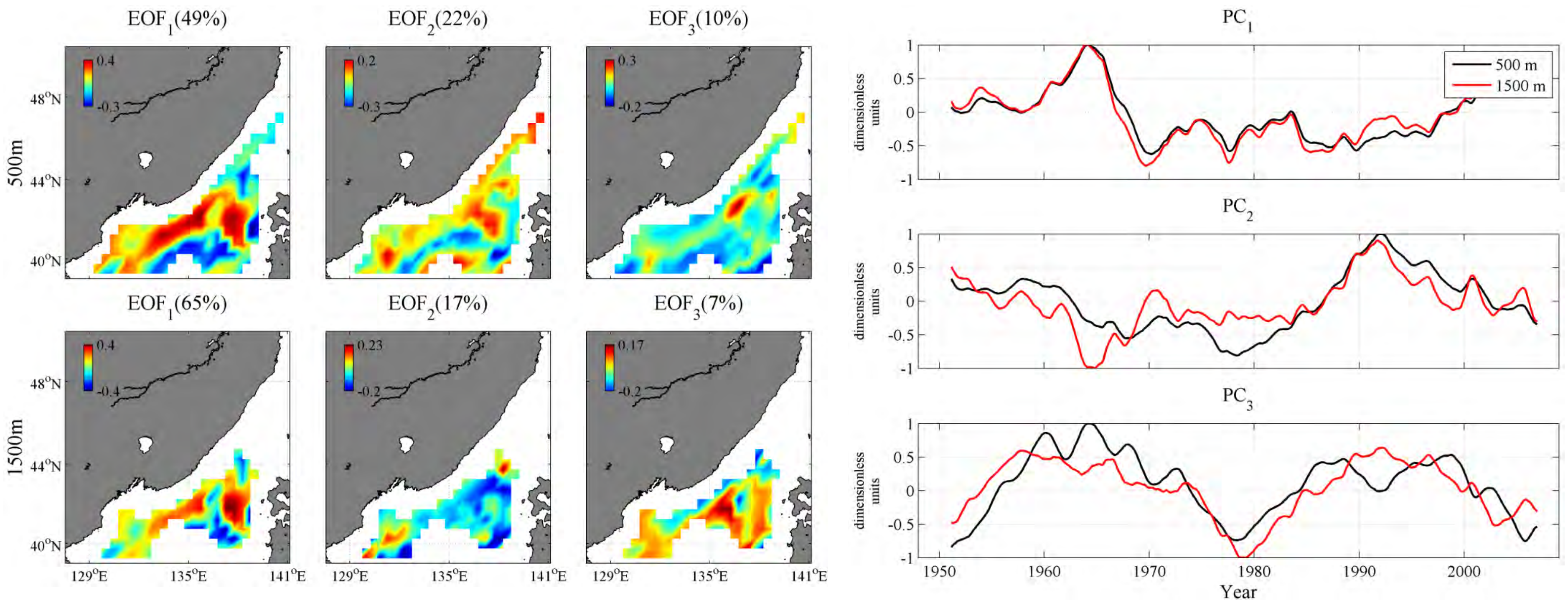
where λ is the longitude, φ is the latitude, R is the Earth's radius and f_0 is the Coriolis parameter (40N).

Variability of the cyclonic gyre in the JES
Interannual variability



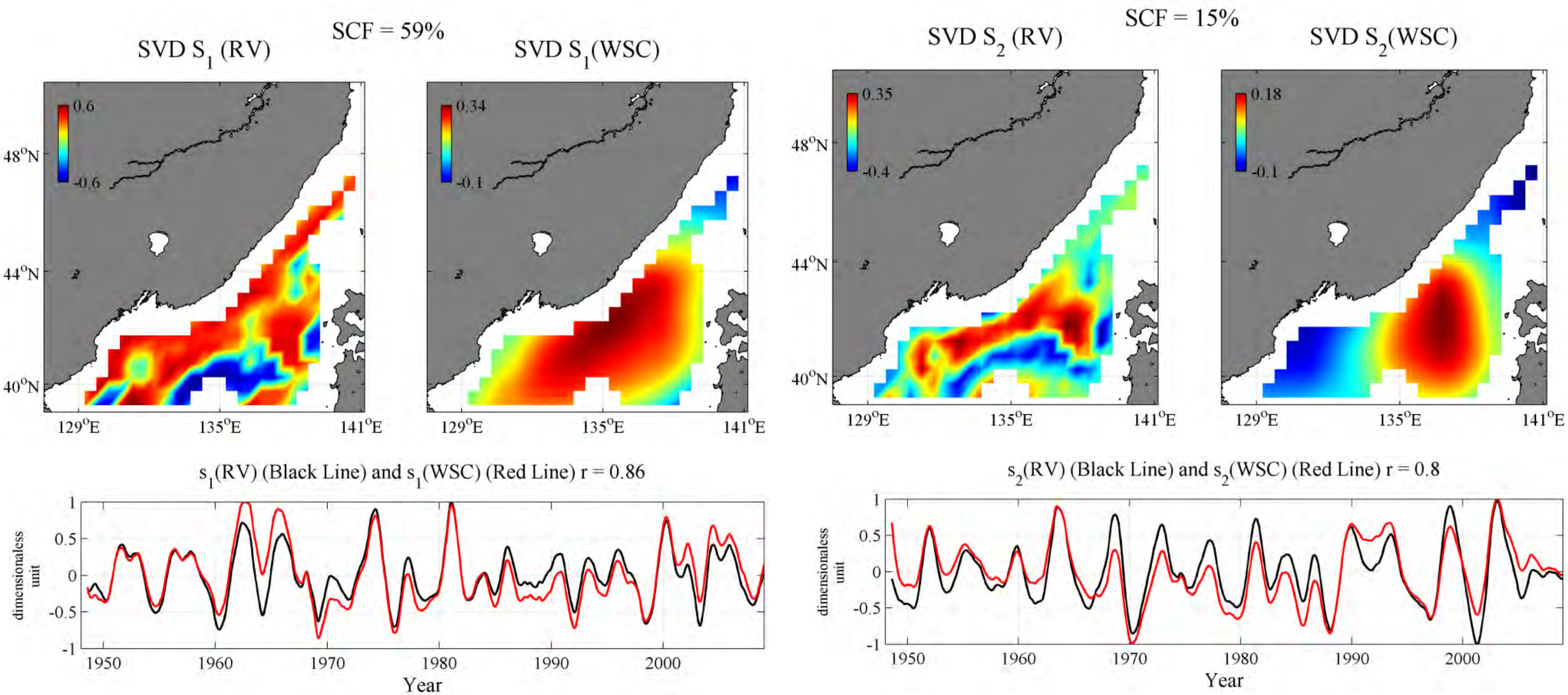
To study the cyclonic gyre variability, we used EOF analysis of RV anomalies. Preliminarily, the RV anomalies were filtered by the moving average with a cutoff period of 6 years. So, we divided the RV anomalies on interannual and decadal. Interannual variability is characterized by the periods of 3, 4 and 5 years. Variability with period of 4 years dominates in the interannual RV anomalies.

Variability of the cyclonic gyre in the JES
Decadal variability



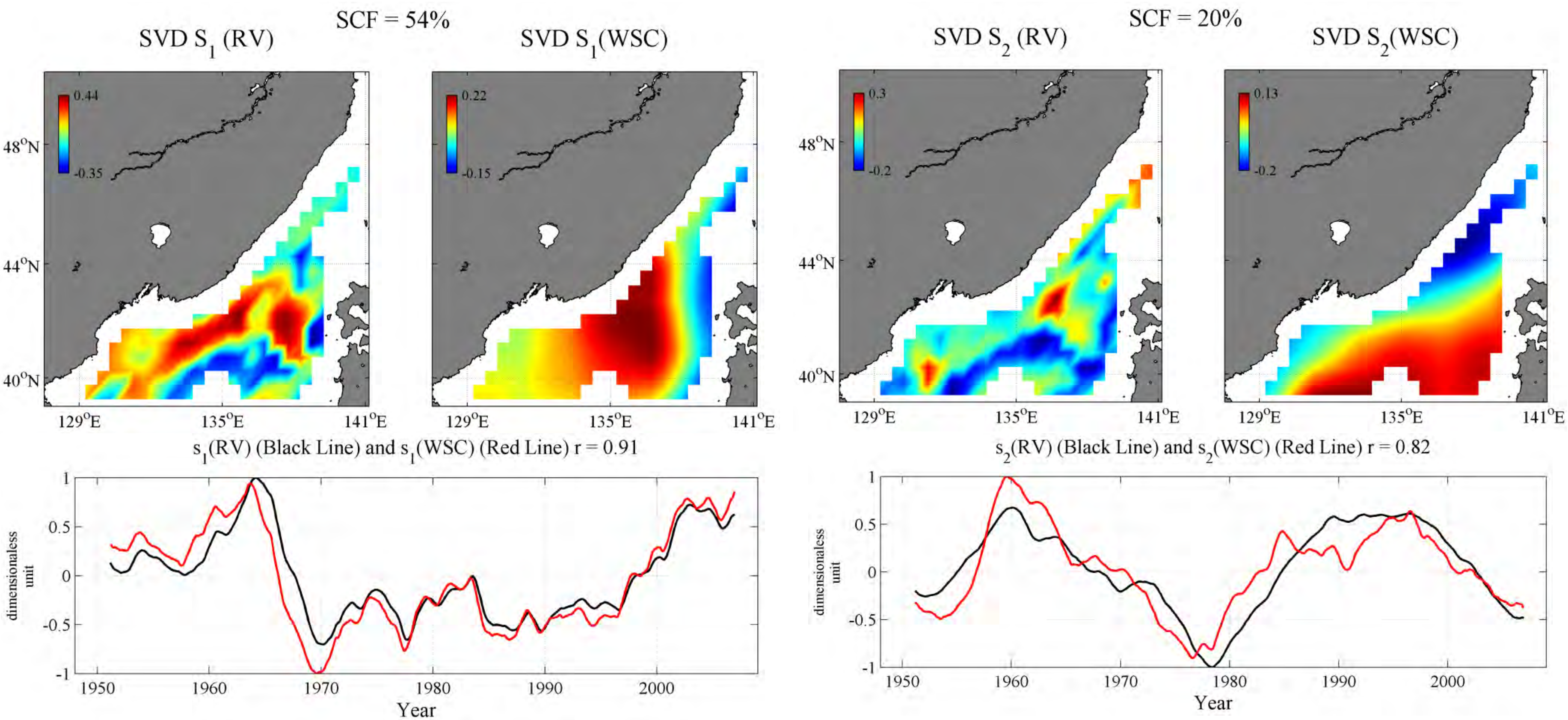
Decadal RV variability is characterized by the strong positive signals in 1965 and 1992 years, which characterize the increase of the cyclonic circulation in the northern JES. The negative signal in 1980 accompanies the decrease of the cyclonic circulation in the northern JES.

Relationships between the relative vorticity (RV) and wind stress curl (WSC), 1948 to 2009 Interannual anomalies



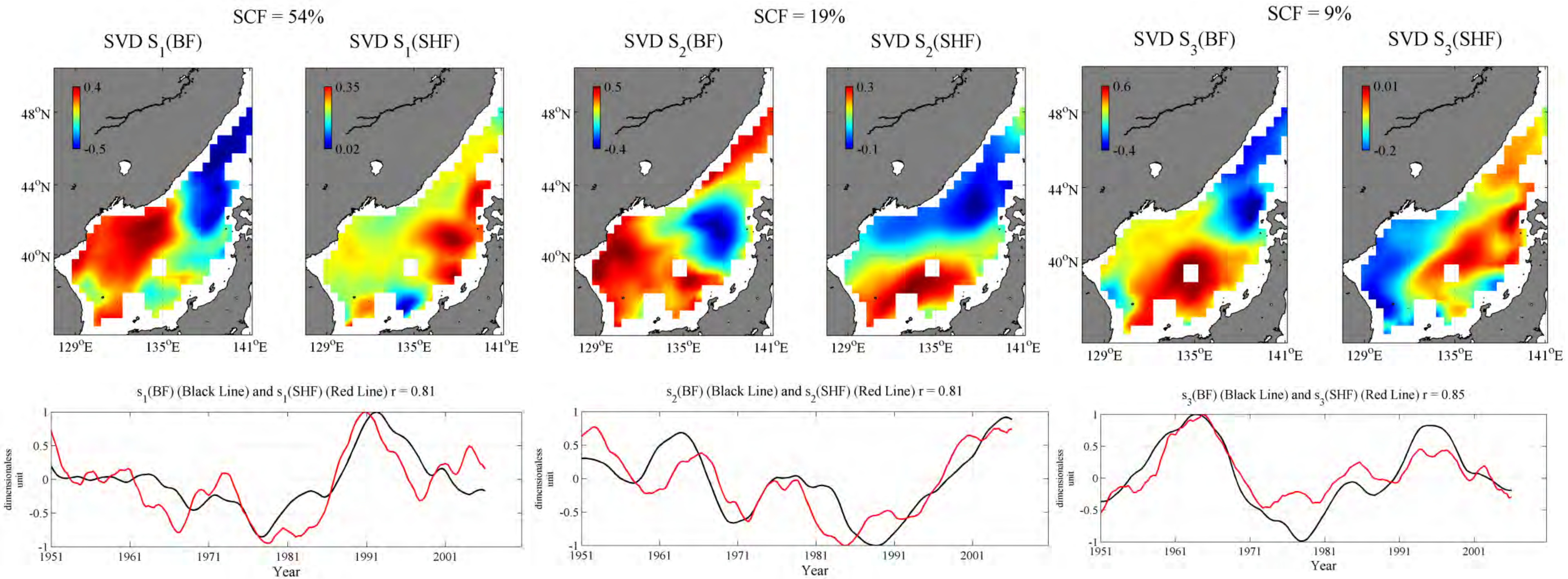
To study influence of the atmospheric forcing on the cyclonic circulation variability we considered the relationships between RV and WSC anomalies based on SVD (Singular Value Decomposition) analysis. There is a significant relationship between RV and WSC on the time scales of 3,4 and 5 years.

Relationships between the relative vorticity (RV) and wind stress curl (WSC), 1948 to 2009 Decadal anomalies



We find the significant relationships between RV and WSC on the decadal time scales. However, the contribution of coupling decadal variability in the WSC anomalies is small. Therefore, it can be other reasons of decadal RV variability. We suppose that the decadal variability of stratification accompanies the decadal RV variability. What can be reason of the decadal variability of stratification?

Relationship between the buoyancy frequency (BF) in intermediate layer and sensible heat flux (SHF) in winter, 1948 to 2009 Decadal anomalies



We find that there is a significant relationship between BF and SHF in winter on the decadal time scale. High coupling occurs between the SHF anomalies in the region of the Tsushime current (nearshore branch) and the negative BF anomalies in the northern JES as well as between the meridional gradient of the SHF and quasi-zonal gradient BF. So, the SHF decadal variability can be other reason of decadal RV variability.

Conclusions

- The model configuration based on the INMOM model for study the influence of atmospheric forcing on circulation variability in the Japan/East Sea was presented. We focused on the cyclonic gyre and its variability in the intermediate and abyssal layers in the northern Japan/East Sea from 1948 to 2009.
- It was found that the cyclonic circulation intensifies in winter and decays in autumn. The cyclonic circulation interannual variability was dominated by the period of 4 years. Decadal variability of the cyclonic circulation was dominated by the strong positive signals in 1965 and 1992, as well as a negative signal in 1980.
- It was found that the interannual variability of the cyclonic circulation results from the interannual variability of the wind stress curl over the Japan/East Sea.
- However, decadal variability of the cyclonic circulation results from both the wind stress curl and stratification. Stratification variability on decadal scales accompanies by the sensible heat flux variability over the Japan/East Sea in winter.