Impact of atmospheric forcing on heat content variability in the sub-surface layer in the Japan/East Sea, 1948-2009

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Motivation

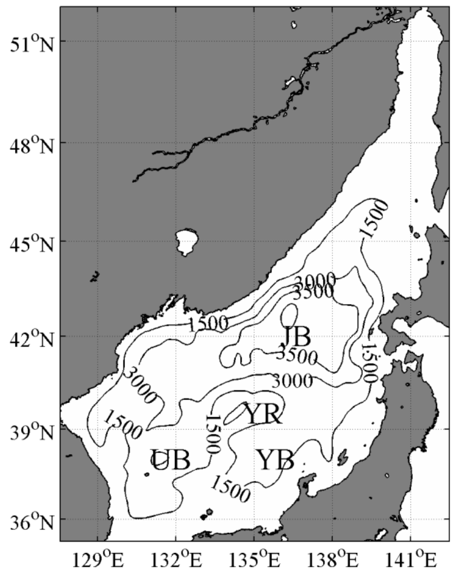
- Global heat content of the upper ocean shows an increasing quasi-linear trend. Conversely, the upper ocean heat content averaged over the marginal seas shows significant decadal variations.
- The Japan/East Sea (JES) is one of the marginal seas in the North Pacific. Upper heat content of the JES and its variability are very important problems in the regional climate modelling.
- The JES is connected by shallow and narrow straits to the North Pacific and adjacent seas. So, we face the problem of the separating of the atmospheric impact from the strait influence on the JES heat content and its variability.

Outline

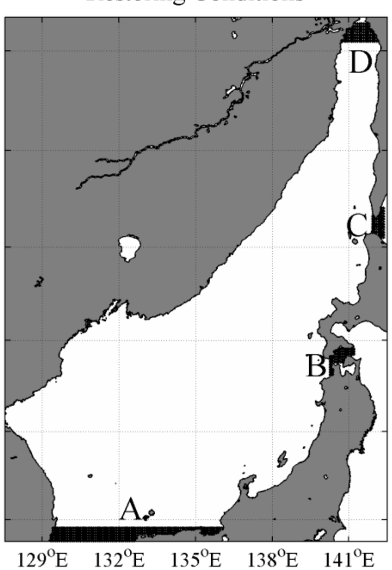
1. Model configuration description
2. Verification and validation of the model configuration
3. Spatial temporal variability of the upper heat content in the JES
4. Relationships between the upper heat content anomalies and sea level pressure over the JES, 1948 to 2009
5. Relationships between the sea level pressure and Arctic Oscillation and North-Pacific Oscillation, 1948 to 2009
6. Conclusions

INMOM Parameters, Initial Fields and Forcing

Bottom Topography
in the JES



Restoring Conditions



INMOM is a three-dimensional, free surface, s-coordinate circulation model. The hydrostatic and Boussinesq approximations are used by the model.

The horizontal resolution is $1/12^0$ and 30 vertical sigma-levels

Time step is 180 second.

Initial temperature and salinity were taken from the WOA 2001.

Open boundary conditions(A,B,C,D)

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

Atmosphere forcing

CORE (Common Ocean-ice Reference Experiments) dataset:

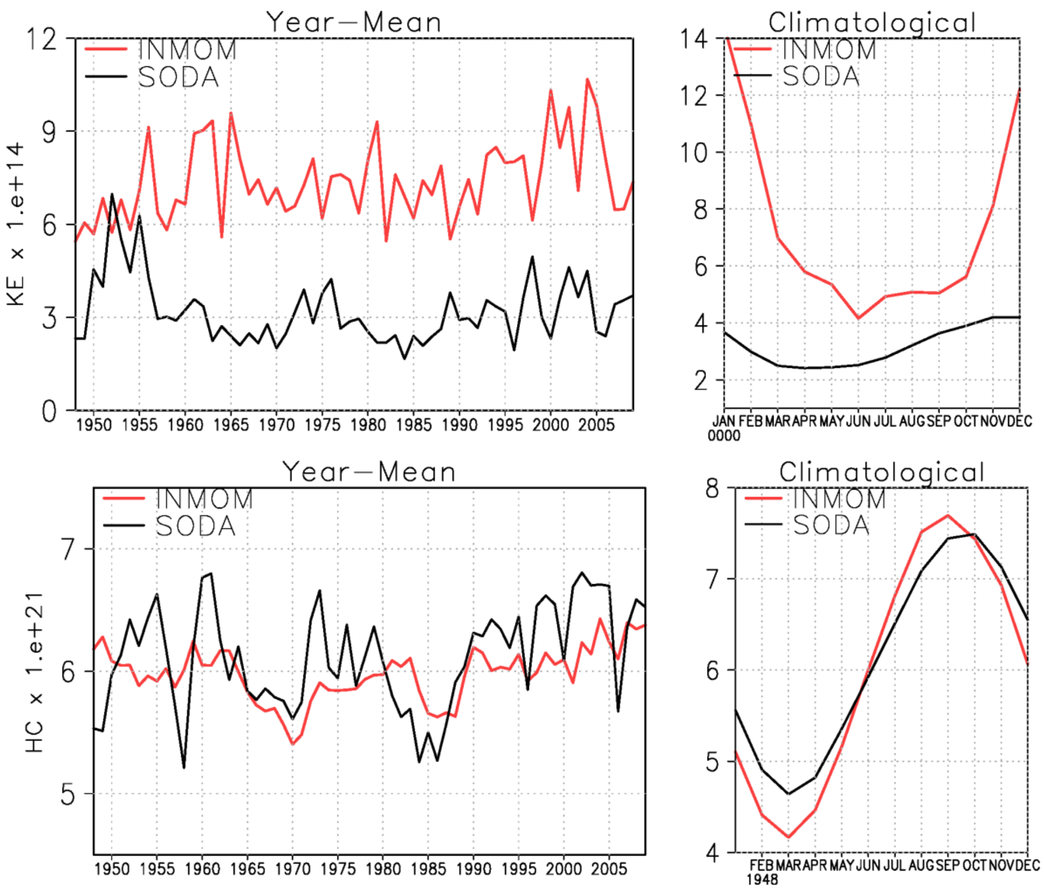
-monthly mean precipitation

-daily short- and longwave radiation

-six-hourly temperature, humidity, wind speed at 10 m and sea level pressure

Atmospheric data dimension is 192x94, time period is 1948-2009 (62 years).

Kinetic Energy and Heat Content Comparison of the INMOM and SODA 2.2.4



Kinetic Energy (KE) and Heat Content (HC) of the upper layer (H = 300 m) in the JES

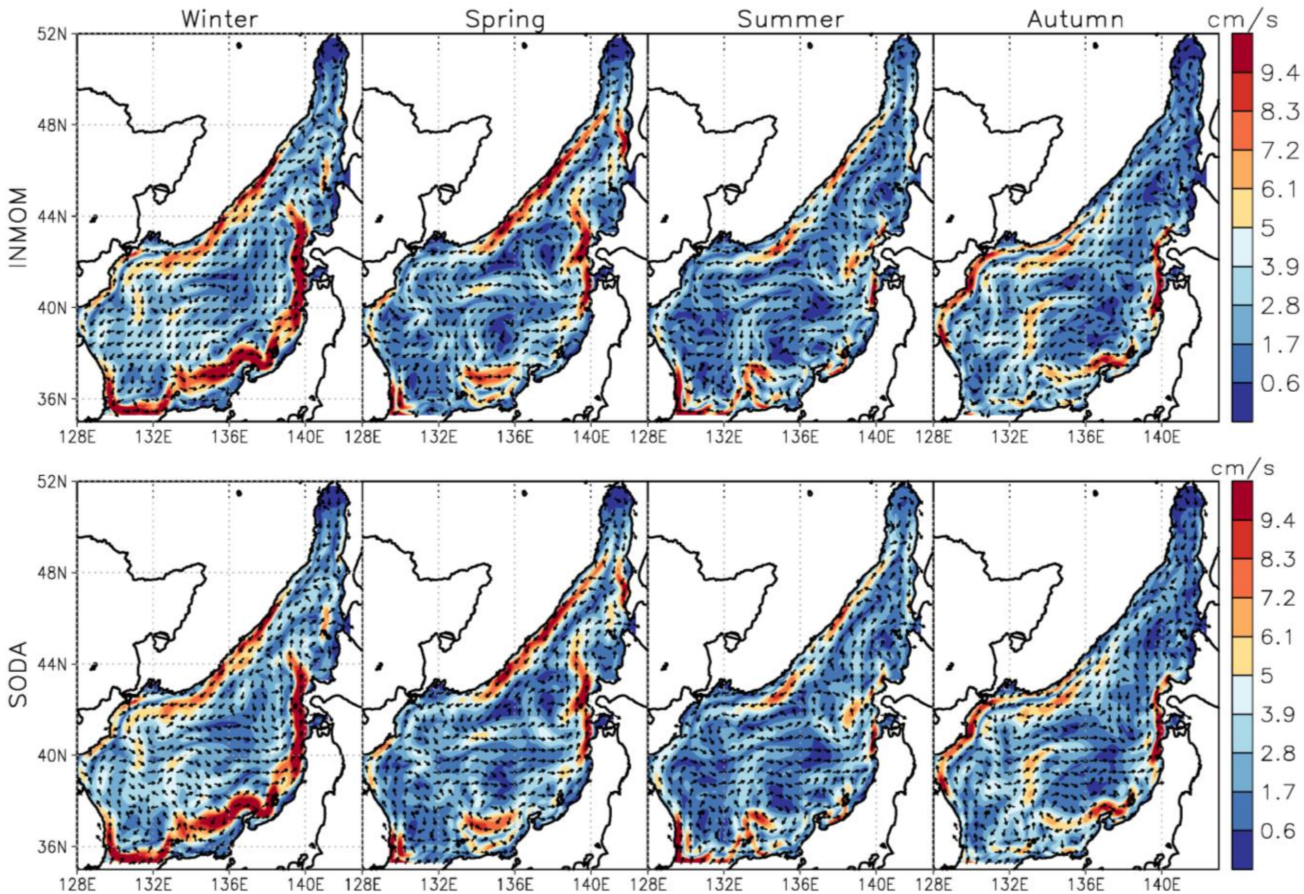
$$KE = \int_0^H \iint \bar{\rho} \frac{\bar{u}^2 + \bar{v}^2}{2} dSdz$$

$$HC = \int_0^H \iint \bar{\rho}_1 c_p \bar{T} dSdz$$

$(\bar{\ })$ devotes the monthly mean

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

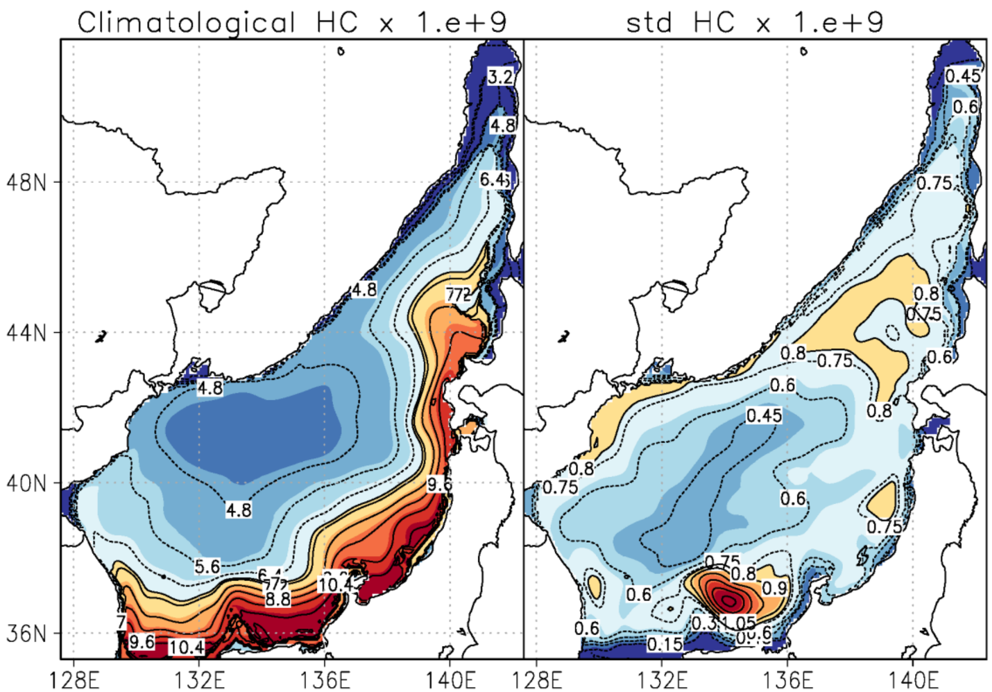
Climatological circulation in the JES
Comparison of the INMOM and SODA reanalysis



Climatological circulation averaged in the JES upper layer obtained from the INMOM hindcast simulations (upper panel) and extracted from the SODA reanalysis (lower panel)

- Basin-scale circulation features obtained from the numerical simulations: the cyclonic gyre in the northern JES, the nearshore branch of the Tsushima Current and the Liman Cold Current are very similar to those extracted from the SODA reanalysis.
- Discrepancies between these datasets are observed in the region of the Subpolar Front (along the latitude of 41N) and south-western JES.

Heat Content of the upper layer in the JES obtained from INMOM hindcast simulations



Climatological mean (left) and standard deviation (right) of the upper heat content in the JES. Scale is J/m^2

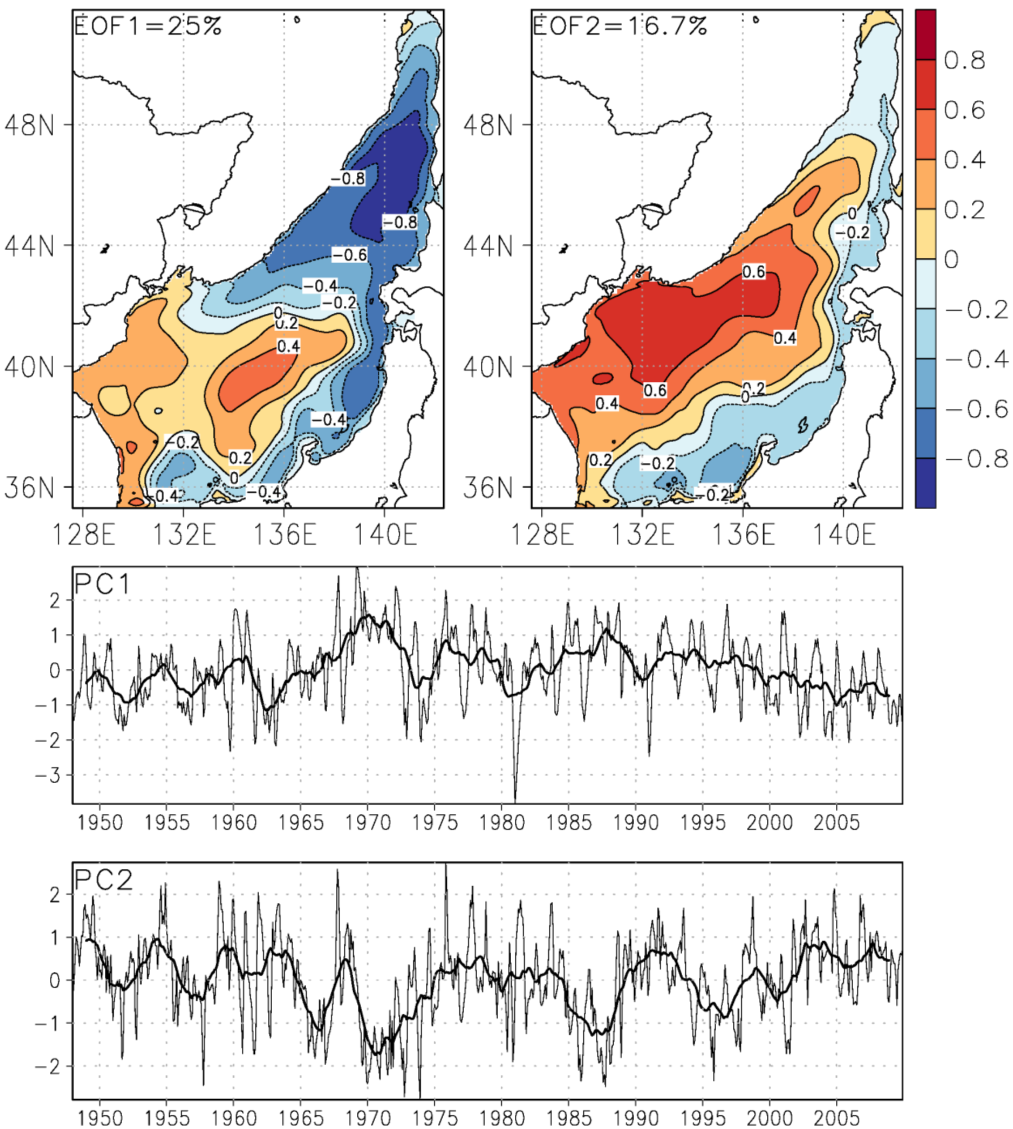
The climatological mean of the upper heat content shows its large values in the south- and north-eastern part of the JES.

Climatological mean pattern reflects the influence of the cyclonic gyre, which is predominate in the basin-scale circulation of the JES induced by mainly atmospheric forcing.

A strong meridional gradient occurs southward the latitude associated with the Subpolar Front (41N).

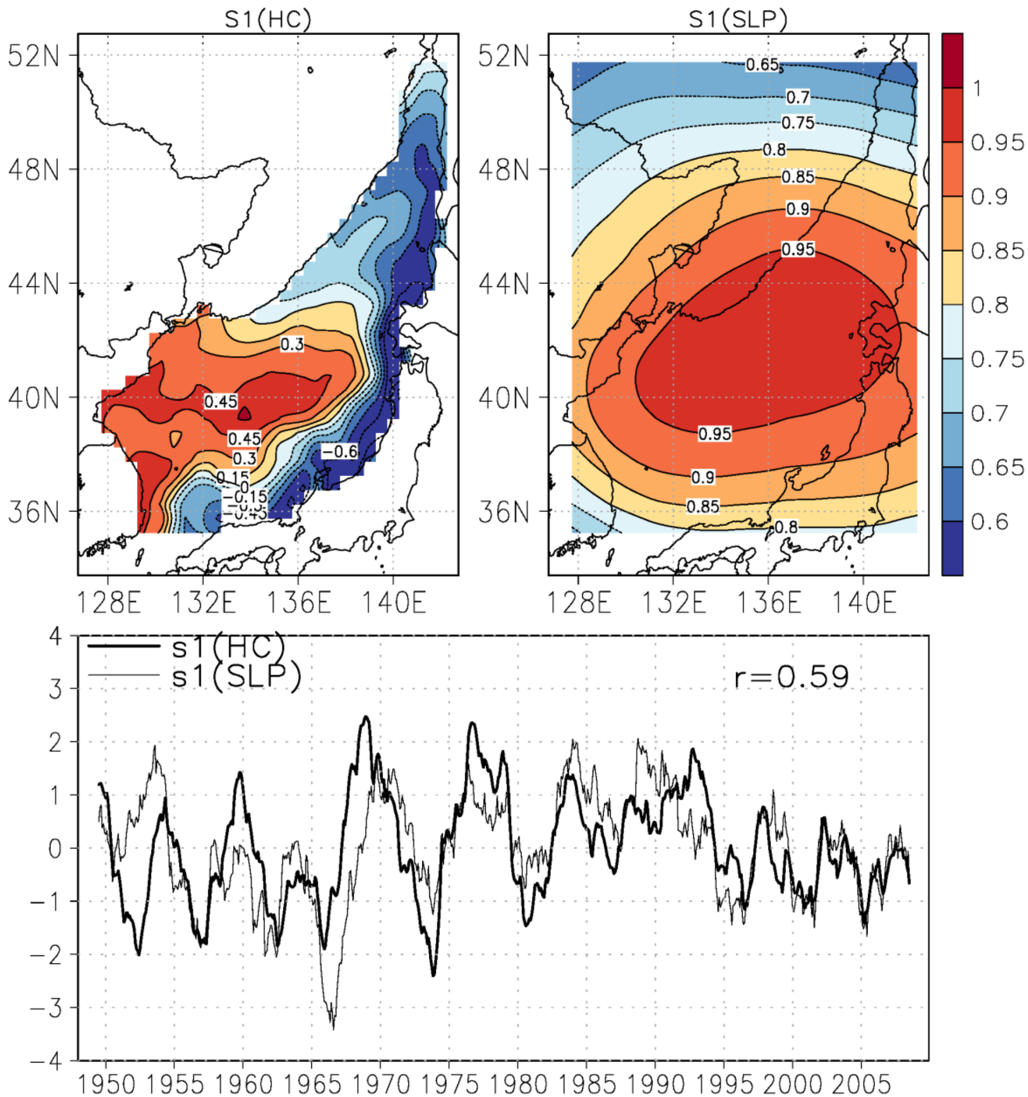
The standard deviation is relatively large in the southern, northern and north-western parts of the JES, while it is relatively small in the central part of the JES.

Variability of the upper heat content in the JES, 1948-2009



- Spatial structure of the leading EOF mode is presented as homogeneous correlation map (HCM). As according to the HCM corresponding to the leading EOF modes, high correlation coefficients are showed in the central, northern and north-western part of the JES.
- Time series of the principal component corresponding to the first EOF mode (PC1) is characterized by significant interannual variability on the time scale of 3-5 years. In addition, a quasi-linear trend is observed from 1990, which is associated with the heat loss in the central and south-western part of the JES and the heat storing in the northern JES.
- On the other hand, time series of the principal component of the second EOF mode (PC2) is characterized by significant intra-decadal (5-7) and decadal variability. In addition, an event with the time scale of 15-17 year (from 1970 to 1987-87) is observed.

Relationships between the Heat Content and Sea Level Pressure First SVD mode (SFC=65%)

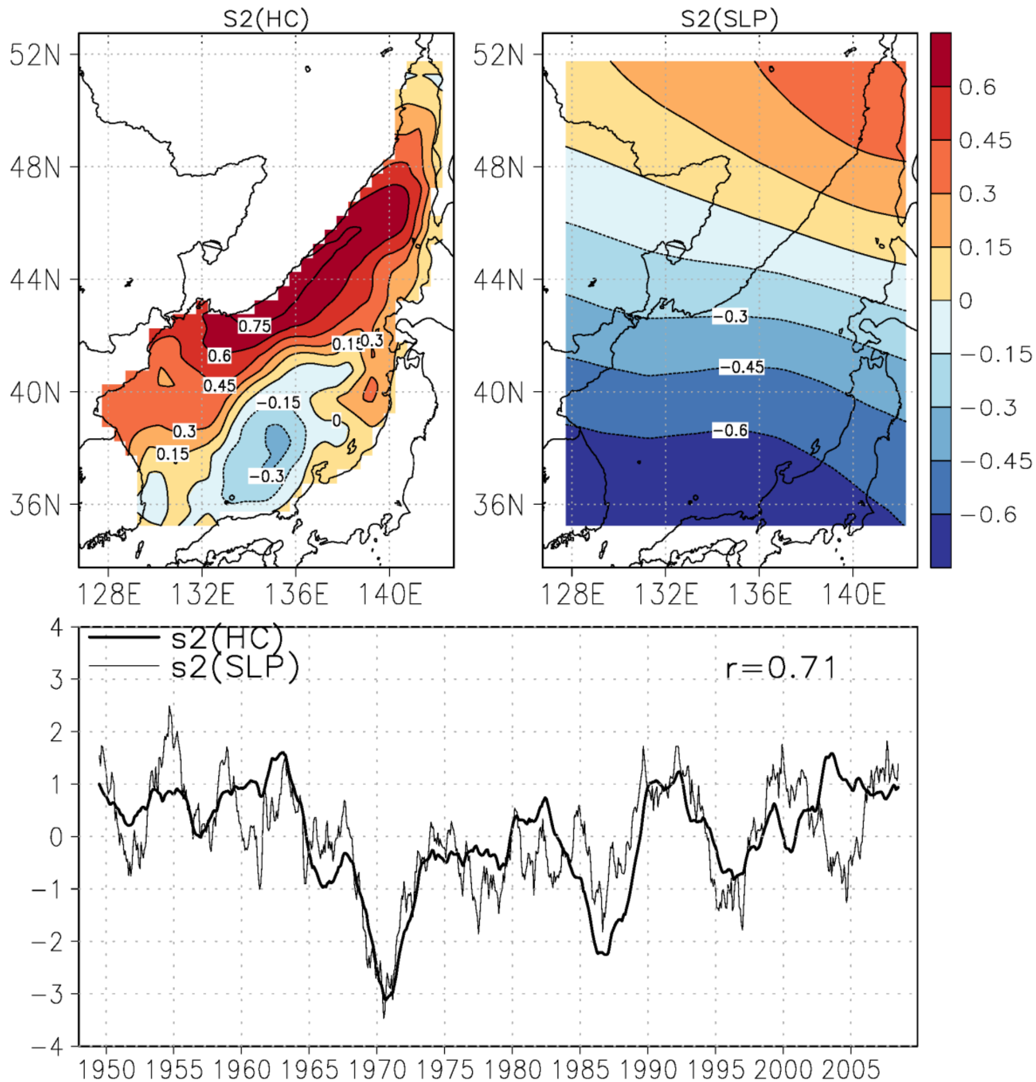


Spatial structure of the leading SVD mode is presented as the homogeneous correlation map (HCM).

As according to the HCM corresponding to the first SVD mode, the upper heat content variability in the central part of the JES is associated with the monopole spatial structure of the sea level pressure over the JES.

As according to time series of the expansion coefficients corresponding to the first SVD mode, significant relationship (correlation coefficient = 0.59) between upper heat content and sea level pressure variations occurs on the interannual time scale of 3-5 years with the time lag of 1-2 years.

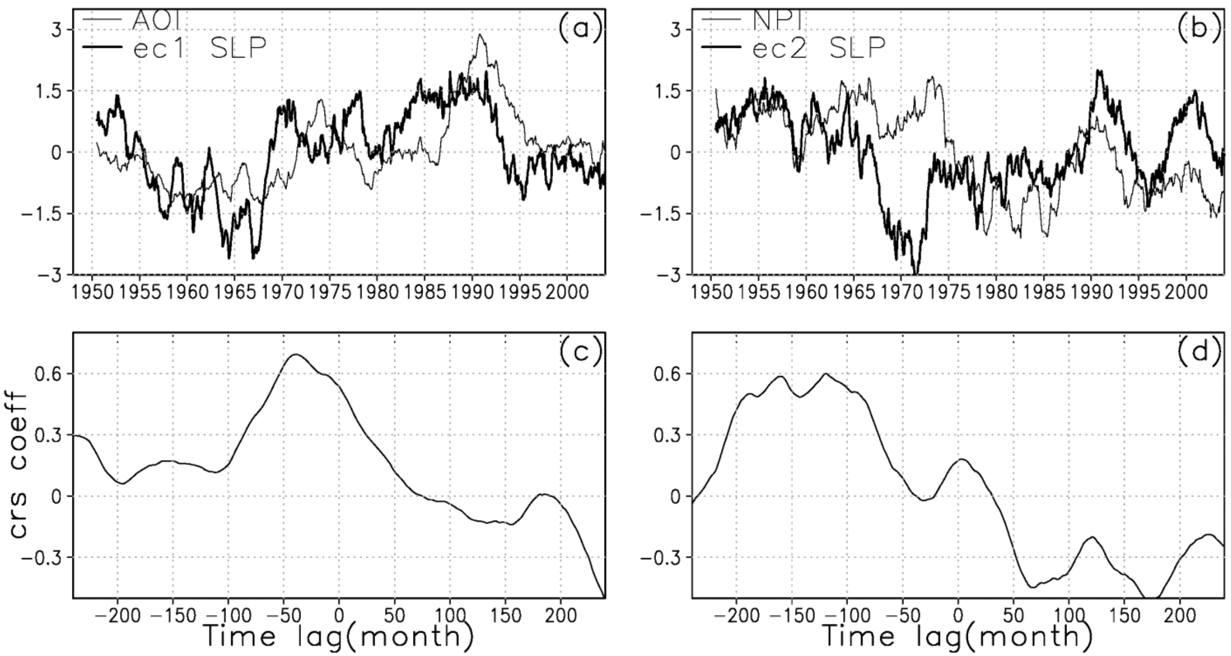
Relationships between the Heat Content and Sea Level Pressure Second SVD mode (SFC=17%)



As according to the HCM corresponding to the second SVD mode, the upper heat content variability in the north-western JES is associated with the north-south seesaw spatial structure of the sea level pressure over the JES.

- Even though a small value of the SFC corresponding to the second SVD mode, significant relationship (correlation coefficient = 0.71) between the upper heat content and sea level pressure variations occurs on intra-decadal and decadal time scales.
- As according to time series of the expansion coefficients corresponding to the second SVD mode, significant heat loss in 1970 and 1985 years and gradual heat storing complicated by intra-decadal variability with the time scale of 5-7 years are associated with the increasing of the sea level pressure in northern JES and the decreasing of the sea level pressure in southern JES.

Relationships between the Sea Level Pressure and Arctic Oscillation and North-Pacific Oscillations



(a) Time series of the Arctic Oscillation Index (AOI) and expansion coefficient corresponding to the first SVD mode (ec1 SLP) and (b) time series of the North-Pacific Index (NPI) and expansion coefficient corresponding to the second SVD mode (ec2 SLP). Cross-correlation functions for the AOI and ec1 SLP (c) and for the NPI and ec2 SLP (d).

- Analysis of the cross-correlation functions shows that the SLP intra-decadal variations, driving the upper heat content intra-decadal variations, are associated with AOI with the time lag of 3.3 years.
- At the same time, the SLP decadal variations, driving the upper heat content decadal variations, are associated with NPI with the time lag of 12 years. .

Conclusions

- Based on the INMOM hindcast numerical simulations, the upper heat content variability in the Japan/East Sea (JES) was considered from 1948 to 2009. We assessed the impact of atmospheric forcing on the upper heat content long-time variability.
- Comparison of the simulated circulation and that extracted from the SODA reanalysis showed that the integrated heat content and kinetic energy of the simulated circulation were good agreement with those extracted from the SODA reanalysis.
- Analysis of the simulated upper heat content variability showed that its significant was observed in the central part of the JES on the time scale of 3-5 years and the northern and north-western of the JES on the time scale of 5-7 years. In addition, we observed the events associated with significant upper heat loss in 1970 and 1987-87 years in the north-western of the JES.
- We established that the upper heat content variability on the time scale of 3-5 years is associated with the Arctic Oscillation with the time lag of 3.3 years. On the other hand, the upper heat content decadal variability is associated with the North-Pacific Oscillation with the time lag of 12 years.