Heat Content Variations in the Southwestern East/Japan Sea

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1. Introduction

**WHY HEAT CONTENT??**

The ocean heat content may be the dominant component of the variability of the Earth’s heat balance.

* The heat content of the world ocean increased between mid 1950s and mid-2000s.

Levitus et al. (2005)
THE EAST/JAPAN SEA (EJS)

- Deep marginal sea in the northwestern Pacific (ave./max. depth ~ 1700/3500 m)
- 3 deep basins (JB, UB, YB)
- Upper layer inflow-outflow system of the Tsushima Current, warm & thin (<200m) upper circulation south of the SPF over a thick cold water layer (over 90% in its volume, $\theta<1.0^\circ$C)
- Thermohaline circulation: deep water formation and southward discharge
- Rapid ventilation timescale ~ 100 years
- Other features: subduction, mesoscale eddies, high productivity (273.0 gC/m²/yr, Kwak et al., 2013)
★ WATER MASSES IN THE UB

- **Tsushima Warm Water**: high T, high S, low DO (major surface inflow)
- In summer it is capped by thin fresh layer.
- **East Sea Intermediate Water**: low θ (1~5°), salinity min. layer, DO max. layer brought into the UB from the JB. Carried by the coastal boundary current or subduction along subpolar front
- **Proper Water** (θ < 1.0°C)
Kim et al. (2001)

* Warming trend in the below 500m during the last more than 40 years.

Yeh et al. (2010)

* Warming trend of SST in the EJS is unclear (decadal variation).

Introduction
Lozier et al. (2008)

Basin-averaged changes can mask important spatial differences.

Na et al. (2011)

Variability of the upper-ocean heat content in the EJS.

* Non-seasonal decadal variation
2. Data and Method

**Temperature data from KODC/NFRDI**

<table>
<thead>
<tr>
<th>Data properties</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td># of stations</td>
<td>36 (deeper than 500m (red))</td>
</tr>
<tr>
<td></td>
<td>22 (shallower than 500m (blue))</td>
</tr>
<tr>
<td>Time interval</td>
<td>Bimonthly (2, 4, 6, 8, 10, 12)</td>
</tr>
<tr>
<td>Depth</td>
<td>Standard depth (m)</td>
</tr>
</tbody>
</table>

Heat content

\[
Q(x, y, z, t) = \sum_d \rho C \left( \frac{T(d) + T(d+1)}{2} \right) (D(d+1) - D(d))
\]

HCA = \[Q(x, y, z, t) - Q(x, y, z, \text{clima})\]

\[C = 4 \times 10^3 J/({}^\circ C \text{ kg})\]
\[\rho = 1025 kg/m^3\]
3. Results

1) Basin-averaged temperature trend profile

* Surface~50m temperature has an warming trend but it is not significant.

* 125~300m temperature has a significant cooling trend.
To find out causes of UHCA and LHCA variations,

1) Horizontal distributions of $T_a$ in each period.

2) Vertical profiles of $T_a$ in each period.

※ $T_a = \text{mean } T \text{ over the each period} - \text{mean } T \text{ over the entire period}$
3) Horizontal distributions of $T_a$

* 30m

Upper layer HCA affected by $T$ over 10°C
* 200m

Lower layer HCA affected by T range 1~5°C
4) Profiles of $T_a$ and depth of isotherms

- Profiles of basin-averaged $T_a$ in each period.

- Annual mean time series of basin-averaged isotherms 10°C, 5°C and 1°C.

<table>
<thead>
<tr>
<th>Water mass</th>
<th>W1</th>
<th>C1</th>
<th>W2</th>
<th>C2</th>
<th>C3</th>
</tr>
</thead>
<tbody>
<tr>
<td>TWW</td>
<td>Strong</td>
<td>Weak</td>
<td>Strong</td>
<td>Strong</td>
<td>Strong</td>
</tr>
<tr>
<td>ESIW</td>
<td>Weak</td>
<td>Strong</td>
<td>Weak</td>
<td>Strong</td>
<td>Strong</td>
</tr>
</tbody>
</table>
5) Comparison with other studies

(1) Basin to basin comparison

Minami et al. (1999) and Cui et al. (2010)

* Temperature at PM5 shows a warming trend.
* Before C2, large fluctuations show in KODC temperature time series but after C2, large fluctuations show in PM5 temperature time series.

▲ Compare the PM5’s temperature (r) at 500m with the basin-averaged KODC temperature data (b) at 500m.
(2) Comparison with the heat content in the EJS

Na et al. (2011), In the EJS

1st CSEOF mode of 0~300m HCA(26%), In the UB

From Feb to Jul
Sign of the UB’s spatial patterns in two cases are positive.
Similar decadal variation shows in box period with 2-year lags (the UB leads) but after this, eastern part of the EJS and the UB shows opposite variation.

From Aug to Jan
Sign of the UB’s spatial patterns in two cases are opposite.
Opposite decadal variation shows in box period with 2-year lags (the UB leads) but after this, eastern part of the EJS and the UB shows similar variation.
(3) Comparison with the neighboring marginal sea

* EOF 1st mode of August BWTa (50m temperature anomaly)

* We will infer possible mechanisms for changing properties of water masses in the UB.

Park et al. (2011) Interannual- to-interdecadal variability of the Yellow Sea Cold Water Mass

- Amplitude
- The 1st EOF mode of 100~400m HCA

* We will infer possible mechanisms for changing properties of water masses in the UB.
4. Conclusion

* Contrary to increasing heat content in the EJS, the HCA in the upper 500m of the southwestern EJS has been decreasing.

* Influence of two water masses is important factor for

In the future,

> We check whether UHCA is affected by heat flux or not.
> Compare atmospheric variables like climate indices, wind stress curl, SLP, SAT and etc with the UHCA and LHCA variations.
> Using reanalysis data, calculating 3 dimensional heat budget.
> ...
THANK YOU