Interannual variability of the ocean surface circulation in the Japan/East Sea

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Regional and coastal ocean forecasting system in Korea

Korea Hydrographic and Oceanographic Administration (KHOA)
Contents

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2. Data and Methods
3. Model Verification
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5. Discussion
6. Summary

Work in progress/Future work
1.1 Background
Japan/East Sea surface currents (2013 / 11 / 20)

KHOA (Korea Hydrographic & Oceanographic Administration)

(SLA_AVISO)

- > 1.0 knot
- > 0.5 knot
- < 0.5 knot

SST (°C)

May 5, 1991 (Park et al., 2007)
Choi et al. (2009)

Color: SSH anomaly
Lines: trajectories of surface drifters


Choi et al., 2012. Geostrophic currents from sea surface height.
1.1 Background

The amplitude time series of the first two EOF modes from 1993 to 2008.

Intensification of EKWC
(relaxation of EKWC)

Meandering

Interannual variations

The amplitude time series of the first two EOF modes from 1993 to 2008.
What causes the interannual variability?

- Winds, SLP in the northwestern Pacific, Siberian High (Minobe et al. 2004; Choi et al. 2009)
- Open boundary condition (inflow and outflow variation) from the North Pacific
- Internal low-frequency variability, nonlinearity of the flow (Holloway et al., 1995; Hirose and Ostrovskii, 2000)
1.2 Objectives

• To reproduce inter-annual variation of surface circulation in the Japan/East Sea (JES)
• To find what induce the inter-annual variability of surface circulation in the JES

1. Inter-annual variation of atmospheric condition (wind, air temperature, pressure, solar radiation, humidity)
2. Inter-annual variation of open boundary condition (inflow and outflow transports, T, S)
3. Internal low-frequency variability within the JES
2. Data and Method

- **ROMS (Regional Ocean Modeling System)**

1. Grid size:
   - Horizontal: 1/32° (3 km)
   - Vertical: 41 layers

2. Topography: ETOPO05

3. Initial Condition:
   - Temperature and Salinity - WOA2001
   - SSH and Current - Northwest Pacific Model (10 km)

4. Open boundary Data - Northwest Pacific Model (10 km)

5. Surface forcing: ECMWF daily data

6. River: Nakdong River

7. Tidal forcing: Oregon TPXO6 (M2, S2, O1, K1, N2, K2, P1, Q1, Mf, Mm 10 constituents)

8. Spin up: 7 years

## Experiment Design

<table>
<thead>
<tr>
<th></th>
<th>Atmospheric Forcing</th>
<th>Open boundary data</th>
<th>Initial</th>
<th>Simulation</th>
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<tbody>
<tr>
<td><strong>EXP.1 (Control)</strong></td>
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<td><strong>EXP.2 (ATM)</strong></td>
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<td><strong>EXP.3 (OBC)</strong></td>
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<tr>
<td><strong>EXP.4 (ITV)</strong></td>
<td>Wind: 2005 daily Others: Monthly mean seasonal</td>
<td>Monthly Mean seasonal</td>
<td>2004.01</td>
<td>10 yr</td>
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<td>2004-2008 daily</td>
<td>2004-2008</td>
<td>2004.01</td>
<td>5 yr</td>
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<tr>
<td>EXP.2 (ATM)</td>
<td>2004-2008 daily</td>
<td>Monthly Mean seasonal</td>
<td>2004.01</td>
<td>5 yr</td>
</tr>
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</table>
Spin up

Kinetic Energy (2 + 5 years)

Time (year)
Kinetic Energy for ITV simulation
(2 + 10 years)

Spin up

14%
3. Model Verification

Sea Surface Height from satellite altimeter and surface geostrophic currents
3. Model Verification
Temperature Observation along NFRDI line 105
Temperature CI = 2°C

2007

NFRDI 105 Line

Control

Feb

Aug

Feb

Aug
3. Model Verification

Horizontal temperature distribution (NFRDI) 
at 10 m and 100 m
Temperature
February 2006

Temperature
August 2006

CI = 2°C
Temperature
February 2007

Obs. 10°C

Model

Temperature
August 2007

Obs. 10°C

Model
• Control model produces the surface currents comparable to the surface gestrophiic currents from the satellite altimetry data

• Horizontal and vertical distribution of temperature is similar to the observation in the southwestern part of the JES

• Temperature is higher than the observation below the seasonal thermocline in the model

• Excess number of eddies in the northern part of the JES
4. Result

Effects of ITV, atmospheric forcing, and open boundary data on

4.1 Sea Surface Temperature

4.2 Sea Surface Height
   (1) Mean SSH
   (2) RMS of SSH anomaly

4.3 Variation of temperature at 100 m
4. Result

4.1 Root Mean Square Difference for SST and SSH

- \( \text{rmsd} = \sqrt{\frac{\sum_{i=1}^{n} (M_i - O_i)^2}{n}} \)
- \( M_i \): Modeled value at i grid cell
- \( O_i \): Observed value at i grid cell
<table>
<thead>
<tr>
<th>Simulations</th>
<th>SST (°C)</th>
<th>SSH (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>1.91</td>
<td>0.1014</td>
</tr>
<tr>
<td>ATM</td>
<td>2.02</td>
<td>0.1082</td>
</tr>
<tr>
<td>OBC</td>
<td>1.75</td>
<td>0.0942</td>
</tr>
<tr>
<td>ITV</td>
<td>1.80</td>
<td>0.1075</td>
</tr>
</tbody>
</table>
4.2.1. Mean SSH (2004-2008)

Mean Dynamic Topography

Hydrographic and Satellite altimeter data
4.2.2. RMS of SSH anomaly (Variability)

Nonseasonal SSH Variability (RMS)

Satellite altimeter data

- Control model
- ATM model
- OBC model
- ITV model
4.2.2. RMS of SSH anomaly (Variability)

Nonseasonal SSH Variability (RMS)

Satellite Altimeter data
4.3 Variation of Temperature at 100 m

Contour interval = 1°C

Red line indicates 10°C isotherm
10°C isotherm at 100 m in February

Temperature Variance
Minobe et al. (2004)
10°C isotherm at 100 m in August

Temperature Variance Minobe et al. (2004)
• RMSDs of SST and SSH between models and the observation are about 1.9°C and 10 cm

• When the interannual variations of open boundary data are included (OBC model), RMSDs of SST and SSH decrease relative to those from mean seasonal forcing (ITV model)

• When the interannual variations of atmospheric forcing are included (ATM and Control models), RMSDs of SST and SSH did not decrease
• RMSDs of SST and SSH between models and the observation are about 1.9°C and 10 cm

• When the interannual variations of open boundary data are included (OBC model), RMSDs of SST and SSH decrease relative to those from mean seasonal forcing (ITV model)

• When the interannual variations of atmospheric forcing are included (ATM and Control models), RMSDs of SST and SSH did not decrease

• Interannual variations in the Yamato and Ulleung Basin are related to the internal low-frequency variability of the flow.

• Enhanced Interannual variations in the Ulleung Basin might be related to the interannual variations of OBC and ATM forcing
5. Discussion

Why do we have large (1.9°C) SST RMSD between satellite observation and models?

Why there are many eddies in the northern part of the JES?
Difference in SST (Model – Satellite)

Difference of Sep.

SEP

Difference of Oct.

OCT

Difference of Nov.

NOV

Difference of Dec.

DEC

Difference of Jan.

JAN

Difference of Feb.

FEB
WOD09

Temperature
February
100 m

Temperature CI = 1°C

Control Model (5 year mean)

Temperature - Depth 100 m
Date: Feb

Temperature - Depth 100 m
Date: Feb
Temperature CI = 1°C
WOD09

Control Model (5 year mean)

Temperature CI = 2°C

Feb

Aug

WOD09 - Lon.: 134.125
Date: Feb

Temperature - Model Lon. 134.125
Date: Feb

WOD09 - Lon.: 134.125
Date: Aug

Temperature - Model Lon. 134.125
Date: Aug
6. Summary

• Circulation of the Japan/East Sea was simulated from 2004 to 2008 and compared with the observation (satellite SST, SSH, and hydrographic data)

• Effects of atmospheric forcing, open boundary data, and internal low-frequency variability were examined
  1. **ITV** makes interannual variability of surface currents in the **Yamato Basin and the Ulleung Basin**
  2. Interannual variations of open boundary data (OBC model) improved SST and SSH relative to those from mean seasonal forcing (ITV model). ATM model did not improved SST and SSH.
  3. **Interannual variations in the Ulleung Basin might be related to the interannul variations of OBC and ATM forcing**
Work in progress/Future work

- Fix warm SST bias in the northern part of the JES during winter and improve intermediate water formation and cyclonic circulation in the northern JES
  - horizontal viscosity
  - wind, air temperature
  - surface heat flux
  - vertical mixing

- Extend the numerical simulation from 1991 to 2010 (20 years)

- Calculate quantitative contributions on the interannual variations from ITV, OBC, and ATM

- Dynamics: wind stress curl, vorticity, and instability

- Data assimilation and operational system
Thank you
Steady forcing (Holloway et al., 1995)

(a) Low Kinetic Energy

(b) High Kinetic Energy
Steady forcing (marked +) and mean seasonal forcing (Holloway et al., 1995)

Internal low-frequency Variability (ITV)
2006

Temperature CI = 2°C

NFRDI 105 Line

Control Model

Feb

Oct

Feb

Oct
Nonseasonal SSH Variability (RMS)

Satellite altimeter data

Control model

RMS of Daily mean SSH

RMS of low-pass filtered SSH (6 weeks)
10°C isotherm at 100 m in April

Temperature Variance
Minobe et al. (2004)
10°C isotherm at 100 m in October

Temperature Variance Minobe et al. (2004)
RMS of SSH anomaly from other model
\[
\text{Ratio} = \frac{\text{RMS of SSH anomaly from ITV model}}{\text{RMS of SSH anomaly from other model}}
\]
RMS of SSH anomaly from ITV model

(Nonseasonal variation of SSH)
SST difference between model and observation in the northern part of the Japan/East Sea

Model (1 m Temperature) – Observation (Satellite SST)
observation

\( Q_s \text{(W/m}^2\text{)} \)

(d) Oct.

model

+30W/m\(^2\)

+20W/m\(^2\)
Fig. 10. Spatial distribution of the $Q_{\text{net}}$