Coastal upwelling and its ecological effects in the northwestern Japan Sea

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Main geographic features

- Deep semi-isolated basin (>3500 m), narrow shelf
- Along slope current, shelf waves, coastal eddies
- Monsoon winds, upwelling
- Strong seasonal variation of SST, SSS and stratification
Short-term variation of water temperature along Primorye Coast

POI and TINRO moorings data:

Abrupt short-term variations the same magnitude as seasonal ones - of 5-10 °C

Should impact on:
- Fishery and aquaculture (shell-fishes, sea-urchin, laminaria)
- Biodiversity
- Recreation and health etc.
Water temperature variability – bottom moorings

Variability of bottom water temperature at 20 m depth at the shelf of Primorye from August through April (2003-2004)
Objectives

to understand main physical processes responsible for abrupt changes of water temperature and other properties at the Primorye coast in Fall season and an ecosystem response to these changes

Data

- two repeated ship surveys October 12-November 4, 2000 (CTD, chemical, biological)
- NOAA AVHRR images
- SeaWiFS ocean color images
- hydrometeorological data
In situ observations

PICES JES Cruise 2000, r/v Professor Gagarinskiy
1 leg - Oct 12-18 (blue line)
2 leg – Oct 31–Nov 3 (red line)

Measurements:
CTD,
DO,
Nitrates,
Nitrites,
Phosphates,
Silica,
pH, Alkalinity,
Chl-a, PP, plankton
Upwelling Winds

Leg 1 - Oct 12-18
Leg 2 - Oct 31–Nov 3

Gamov

October 2000

Coastal station

NCEP/NCAR Oct.

QuickScat

2000

0 5 10 15 20 25 30 35 40 45 >80 knots
SST Pattern in the northwestern Japan Sea

NOAA AVHRR image for October 15, 2000

Formation of coastal eddies and upwelling event off Primorye on NOAA AVHRR infrared images
SST Structure Changes on Satellite Images

Wind at Cape Gamov Station

October 2000

05.10  12.10  15.10

18.10  21.10  27.10

30.10  02.11

Eddies

Upwelling

Wind speed

Upwelling
SST Changes in Fall Season

- Wind induced upwelling
- Mesoscale eddies formation
- Fast cooling, convection

Formation of coastal eddies and upwelling event off Primorye on NOAA AVHRR infrared images

Slow decrease of SST on the shelf 12-21 and fast drop 21-27.10
Coastal Mesoscale Eddies

Eddies evolution on infrared images

Numerical isopycnal model (Trusenkova, 2004)

with NCEP monthly winds:
- discontinuity and reverse of Prymorye Current
- formation of anticyclonic eddy
Hydrographic sections: different changes at bottom layers at the eastern and western coastal stations

Formation of coastal eddies and upwelling event off Primorye on NOAA AVHRR infrared images

Changes in T, S, density and nutrients along the sections S1 and S3 over 2-3 weeks period

<table>
<thead>
<tr>
<th>ΔT, °C</th>
<th>S1</th>
<th>S3</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 m</td>
<td>3.5</td>
<td>5.2</td>
</tr>
<tr>
<td>50 m</td>
<td>9.6</td>
<td>0.5</td>
</tr>
</tbody>
</table>

S3: Upwelling and convective mixing off Preobrazhenie (134E)
S1: Intrusion of deep sea water onto the shelf of Peter the Great Bay
Chl-a and Primary Production

Observations and Analyses:

Chl-a – filtration and spectrophotometer;

PP – radiocarbon marker (19 stations);

Delayed fluorescence – DF system;

Photic layer depth – Secchi disc;

Nutrients, pH, Talk (pCO2, DIC) – standard

Primary Production Estimation: (Behrenfeld and Falkowski, 1997; Zvalinsky et al., 2002);

\[ PP = 0.66 \times P^b \times C_{chl} \times T_d, \text{ where} \]

\[ P^b - \text{chlorophyll-specific photosynthesis (mgC / mgChl * h)} \]

\[ C_{chl} - \text{mean chlorophyll concentration in a photic layer} \]

\[ T_d - \text{daylight duration} \]

\[ PP = 0.66 \times P^f \times I_{fl} \times T_d, \text{ where} \]

\[ P^f - \text{fluorescence-specific photosynthesis} \]

\[ I_{fl} - \text{mean delayed fluorescence intensity in a photic layer} \]
Chl-a and Primary Production

Increase of Chl and PP by the end of cruise especially at the shelf area

Vertical profiles of Chl a – increase and deepening of max

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<table>
<thead>
<tr>
<th></th>
<th>Shallow stations</th>
<th>Deep stations</th>
<th>Total</th>
</tr>
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<tbody>
<tr>
<td>Leg</td>
<td>L1 L2</td>
<td>L1 L2</td>
<td>L1+L2</td>
</tr>
<tr>
<td>Chl (mg/m³)</td>
<td>0.47 0.77</td>
<td>0.37 0.43</td>
<td>0.45</td>
</tr>
<tr>
<td>Chl (mg/m²)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Range</td>
<td>15.0 8 – 22</td>
<td>18.5 13 – 28</td>
<td>19.5 8 – 30</td>
</tr>
<tr>
<td>Daylight, (hour)</td>
<td>11.1 – 10.8</td>
<td>11.1 – 10.7</td>
<td>11.1 – 10.0</td>
</tr>
<tr>
<td>PAR (mol/m²d)</td>
<td>28 – 27 23 – 22</td>
<td>28 – 26 23 – 22</td>
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<tr>
<td>PP(mgC/m²d)</td>
<td>268 120–400</td>
<td>356 250–450</td>
<td>325 120–520</td>
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Even under decrease of PAR between L1 and L2, increase of Chl and PP by ~60% at shelf area
Chl-a, pCO2, Nutrients

Nutrients:
- L1: PP was limited by low nutrients, esp. Nitrates
- L2: Gradual increase of nutrients caused by weakened stratification and uplift of picnocline

pCO2 profiles:
- increased production in upper layer and destruction in lower layer on L2

Vertical profiles of $T$, $pCO2$, $NO3$, $SiO4$ and Chl $a$ for some stations before (L1) and after (L2) upwelling
Chl-a and Primary Production

Chl a content in a photic layer along the sections – *in situ* (more increasing in the west)

Chl a – SeaWiFS data *(O.Kopelevich, S.Zakharkov, E.Streikhert)*

Daily Primary Production in a photic layer

Before

After
Changes in water mass structure and stratification: wind upwelling, eddies and convection

Intrusion area, wide shelf:
- Initially: well mixed
- Nutrients supply
- Uplift of picnocline
- Convective mixing - upper lr.
- Decrease MLD

Upwelling area, narrow shelf:
- Initially: stratified
- Nutrients supply
- Vertical mixing
- Weakening of stratification
- Increase MLD

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1. The major processes responsible for abrupt changes of physical and biological parameters of the Primorye coast in Fall season are:
Thank you!