#### Patterns of Recent Sea Level Rise in the East/Japan Sea And Their Ecological implication in the Ulleung Basin

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> Science Board Symposium, PICES XIV October 3, 2005 Vladivostok, Russia

### **Content of Presentation**

- 1. Research Background
  - -Issues of global sea level rise (GSLR) -SLR study background in the EJS
- 2. Data Analysis
- 3. Results
  - -General SLR features from coastal tide, T/P and thermosteric sea level (TSL)
  - -Long-term (decadal) trend
  - -Eddy contribution to large SLR rate
  - -Deep water warming effect to SLR
- 4. Ecological aspect in relation to eddy activity in UB
- 5. Summary and conclusion

Warming of the World QCevations et al., 2000 and 2005)

- Heat content (1955 to 1998) Increase by 14.5×10<sup>22</sup>J (0-3000m)
   Mean temperature increase : 0.037 ℃
- -Global mean temp. increase from 0 to 300m ∶ 0.171 ℃ -Warming rate ∶ 0.2W m<sup>-2</sup>
- →The Pacific Ocean has been warming since 1950s
- → substantial change : 0 to 300m in each ocean (the North Atlantic in depth greater than 1000m)

#### Yearly heat content anomaly in the upper 300m



The rate of Gobal Sea Level Rise(GSLR) and its cause (Enigma)

What is the rate of 20<sup>th</sup> Century GSLR?
 0.5–0.7mm/yr or
 1.5–2.0mm/yr ?

2. What is the causes of GSLR? Thermal expansion? Freshwater exports from continents?

□ Cabanes et al.(2001, Science)

Global mean sea level(1955-96)



PSMSL GSLR seems to be overestimated!!! Miller and Douglass (2004) argued this



Antonov et al. (2002, JGR) Spatially averaged (50°S-65°N)5-year running mean



-A decrease in global mean salinity has occurred -This increase of freshwater causes SLR at rate of 1.3±0.5mm/yr



 $\delta h_{eustatic} = (\rho/\Delta\rho) \delta h_{steric} = 36.7 \delta h_{steric} = 1.8 \text{mm/yr}, \text{ Ocean area} = 3.6 \times 10 \text{**8km}^2$ 

If SLR by salinity change is known, SLR due to mass input can be calculated Eustatic rise due to mass input corresponds to 515km<sup>3</sup>/year or 1.4mm/year

20th-century SL remains an enigma
We don't know warming or melting was dominant

#### □ Warming of the EJS region

#### -Report of sea water warming Minami et al.(1999): long-term increase of temp. below 800m and 500m Kim et al.(2001): 0.1-0.5°C warming in the upper 1000m layer over the last 40 years

#### Present study background

Present study backround

- →Interest in examining what the rate of SLR is in marginal sea such as EJS and what the cause of SLR is?
- →If it is due to warming, is it due to deep or upper water warming ?
- →Ecological aspects (later)

#### Example of Warming Evidence in the East/Japan Sea (EJS)

Station coverage over 30 years (1941 to 1969(1973))



#### **2.Data Analysis**

#### Data

- -Tidal record : 20-30 yrs
- -Topex/Poseidon data (9yrs) : '93-'01 -Hydrography data:
- -Hydrography data: Period : '60 - ' 01 or '93-'01 Source : KODC & JODC (JODC :  $0.2^{\circ}x0.2^{\circ}$  or  $0.4^{\circ}x0.4^{\circ}$ )
- -Air Temp. data



#### Analysis

- -Tidal record : anomalies for 13 tidal stations
- -Topex/Poseidon(T/P) data : mean slope for non-tidal residual
- -Temperture data : calculate sea level rise by salinity and temp. change
- -Air Temp. data : anomalies

#### **Comparison of thermosteric sea level and T/P**

#### Yearly Mean Sea level : tidal data





#### Recent 9-year('93-01) increasing rate (Tide gauge)

K. side: 7.7mm/yr

J. side: 6.3mm/yr

Average : 6.5±0.7mm/yr



#### **Comparison of TSL with T/P at three points**

#### **Various Sea Levels**

Steric sea level (SSL) : MSL variation by density (T, S) variation

Thermosteric sea level (TSL) : MSL variation by temp. variation

Harosteric sea level (TSL) : MSL variation by sal. variation

Eustatic sea level (ESL) : MSL variation of added mass by ice melting in the continents



#### Comparison of TSL with T/P at 3 crossover points



#### **Results : SLR rate from TSL & T/P for 9 years**



Min, Max, Mean, StDev: -4.3, 20.5, 6.6, 4.1 mm/yr (N=789) Min, Max, Mean, StDev: -6.3, 32.1, 5.5, 7.6 mm/yr (N=59 stations)



# SLR relation between EJS and World Ocean ?

#### Recent 6yr global SLR

EJS pattern reflects feature in the northwestern Pacific (T/P)



Recent 41yr global SLR (TSL) ~ 0.5mm/yr **3. Results (focusing topics)** 

-Long-term (decadal) trend of TSL

-Inhomogeneous SLR : Eddy contribution to locally large SLR rate ?

-Deep water warming effect to SLR

#### 3. Results : Long-term (decadal) variability of TSL

- -Long term variability Data : 1960 – PDO-like(?) signal : ~15yr oscillation Same pattern in heat content anomaly of Pacific Ocean
- -Recent sea level trend : in increasing phase from 93



#### 3. Results :4 points



#### The cause of inhomogeneity?



Min, Max, Mean, StDev: -4.3, 20.5, 6.6, 4.1 mm/yr (N=789) Min, Max, Mean, StDev: -6.3, 32.1, 5.5, 7.6 mm/yr (N=59 stations)

[ct,col0,range]=[41,40,180] (data file: trk...w4.det)

#### Cause of inhomogeneity : TSL and Temperature anomaly

Temp. anomaly (8C



-Large TA variability by eddy existence





**3. Results** 

#### Time-varying eddy contribution to TSL trend

25



#### 3. Results : Sea Level Rise Effect by deep water warming



#### **3. Results : Biological implication in relation to eddy** activity in the Ulleung Basin

-Eddy intensity seems to be reinforced or intensified over some period
-If eddies shows such a trend over limited time period, can there be biological relation in the Ulleung Basin?





## Annual cycles in phytoplankton abundance in the UB

- In the UB, seasonal change in the mixed layer depth drives the annual chlorophyll patterns which exhibit bimodal increases (spring and autumn blooms).
- After spring blooms, the surface chlorophyll-a in summers decreases down to annual minimum due to nutrient limitation among other things (nitrate values are typically less than 0.3~0.5 μM in August).



## Hypothesis

- If eddies become frequent and strong, they could possibly transport nutrients into upper mixed layer in summer.
- If that is the case, eddy activity would increase surface chlorophyll-a in summer.
- The effects of eddies would be most evident when nutrient limitation is strongest, probably in August.

## Comparison of Chl-a in August

- UB (Ulleung Basin): 130.5~131.5E, 36.5~37.5N
- YB (Yamato Basin): 135~136E, 38~39N
- 12x12 pixels (9km)





## SeaWiFS Chl-a in August



# Possible mechanisms of nutrient transport

- Entrainment of coastal upwelling water
- Isopycnal transport? (Yentsch and Finney, 1985)



#### Summary & Conclusion :

- □ Recent 9 yr('93-'01) SLR feature in East/Japan Sea(EJS)
  - Larger increasing rate than global average('93-'98)
  - T/P result well compared with TSL
- □ Mechanism of sea level rising in the EJS
  - Driven mainly by upper layer warming effect (later in phase with global trend)
  - Subject to decadal pattern (PDO?) of Pacific heat anomaly
  - Deep water warming effect being minor until now
- □ Large SLR pattern in Ulleung & Yamato basins
  - Affected by large decadal pattern influenced by Pacific signal
  - $\rightarrow$  Recent 9-year trend : increasing phase after initial decrease
  - Dominated by eddy intensity (size and duration)
- **Ecological implification** 
  - Reinforced eddy activity increases the surface chlorophyll-a in summer in the Ulleung Basin

## Thank you !