No recent uptake of anthropogenic CO_2 by the East (Japan) Sea

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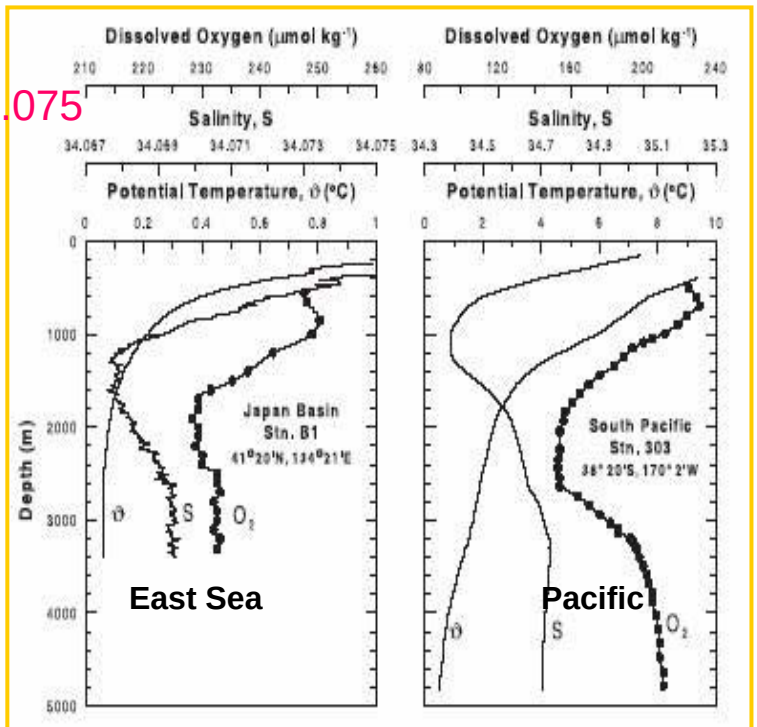
East/Japan Sea

- Semi-closed marginal sea
- Connected to North Pacific via three narrow straits (<150m)
- **Deep water formation**
- **Weak vertical variability**

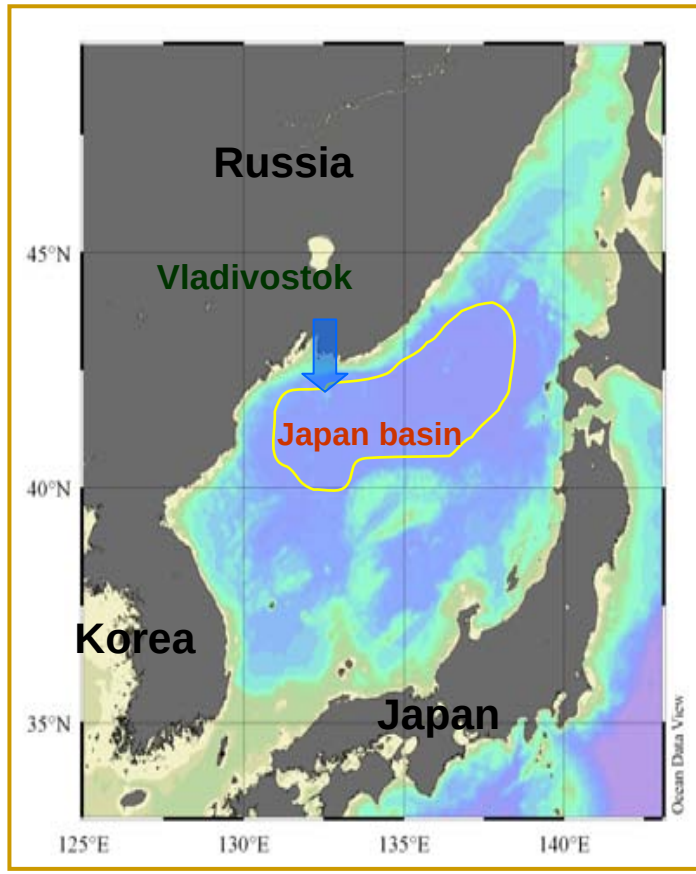
34.067–34.075

0–1°C



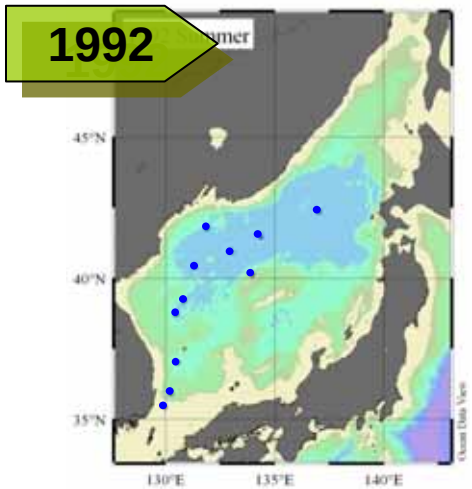
34.3–35.3

0–10°C



(*Kim et al.*, 2002, GRL)

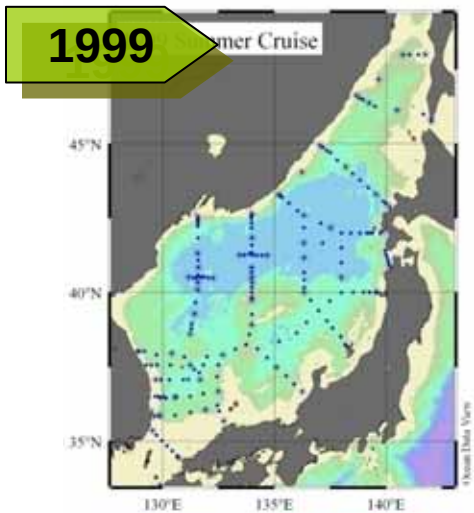
Carbon data sets at different times



- The Kuroshio Edge Exchange Processes-Marginal Sea Studies Expedition
- **1992. 7. 28 - 8. 5**
- **11 hydrographic stations, 214 samples**
- **TCO_2, Talk, Oxygen**

Investigators

- **Chen-Tung Arthur Chen** (*Taiwan*) **and Alenxander S. Bychkov** (*Russia*)

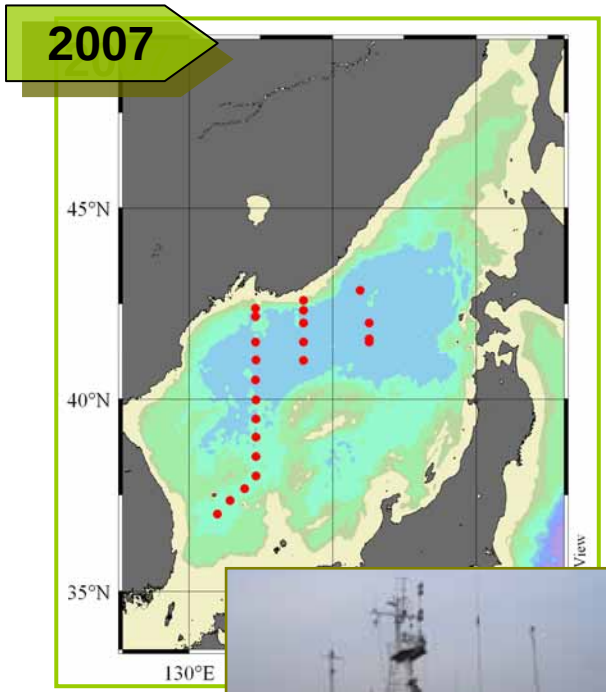


- The Circulation Research of East Asian Marginal Seas and U.S. Office of Naval Research's Japan/East Sea programs
- **1999. 6. 24 - 8. 11**
- **203 hydrographic stations, 3822 samples**
- **Talk, pH, Oxygen, Nutrients, CFC11/12**

Investigators

- **Lynne D. Talley, M. Warner, Dong-Ha Min** *(USA)*
- **P. Tishchenko , V. Luchin, A. Nedashkovskiy, S. Sagalaev** *(Russia)*
- **Kyung-Ryul Kim** *(Korea)*

Korea-Russia Joint Expedition (Prof. K.R. Kim)



- 2007.5.7 - 5.22
- 24 hydrographic stations, 411 samples
- TCO_2, Talk, pH, Oxygen, Nutrients

Investigators

- **P. Tishchenko, V.B. Lobanov** *(V. Il'ichev Pacific Oceanological Institute, Russia)*
- **Kyung-Ryul Kim** *(Seoul National University, Korea)*
- **Kitack Lee** *(Pohang University of Science and Technology, Korea)*

<R/V Professor Gagarinskiy>

Precision

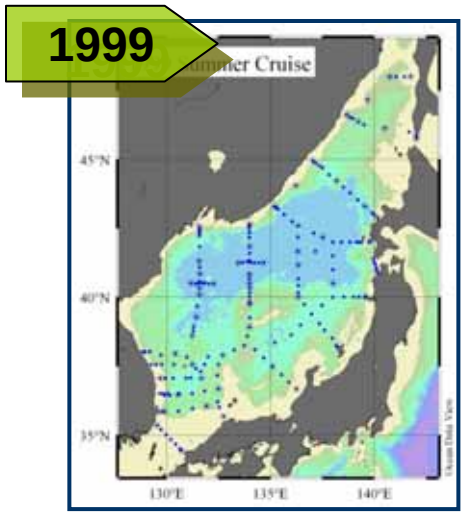
TCO_2	Talk
2.0	1.5

(μmol kg^{-1})

Anthropogenic CO_2 (industrial revolution–1999)

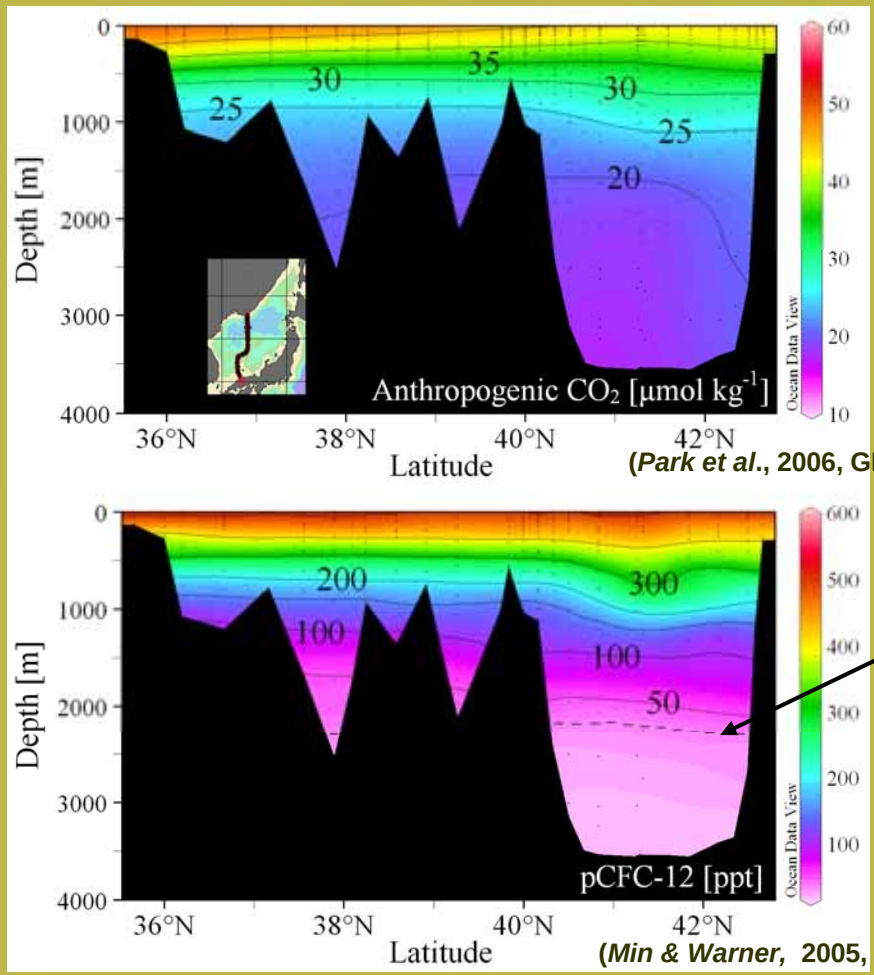
Using C* method (*Gruber et al.*, 1996, GBC)

- **Anthropogenic CO_2 and CFC concentrations**



(*Talley et al.*, 2004, Prog. Oceanogr.)

Total Inventory
0.4 ± 0.06 Pg C



(*Park et al.*, 2006, GBC)

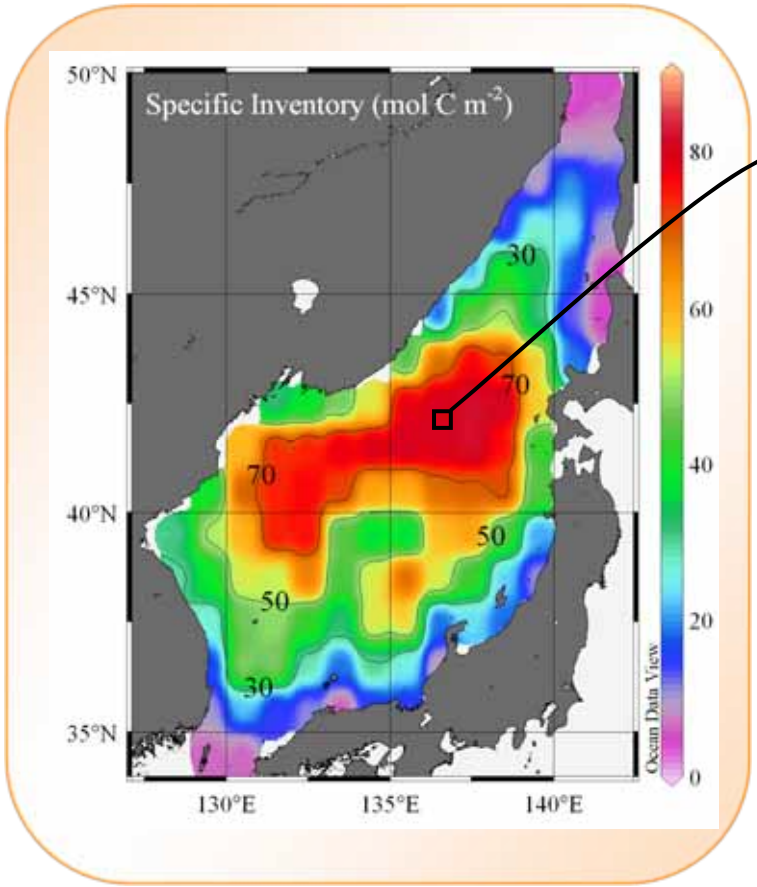
(*Min & Warner*, 2005, Deep Sea Res. II)

CFCage: 40 yrs

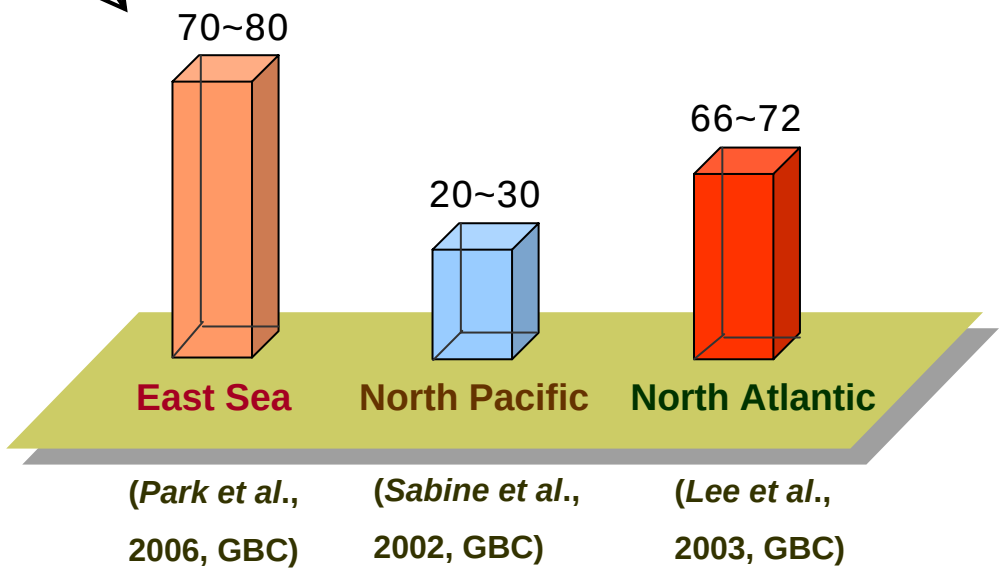
Fast turn-over time (< 100 yrs)

Anthropogenic CO_2 (industrial revolution–1999)

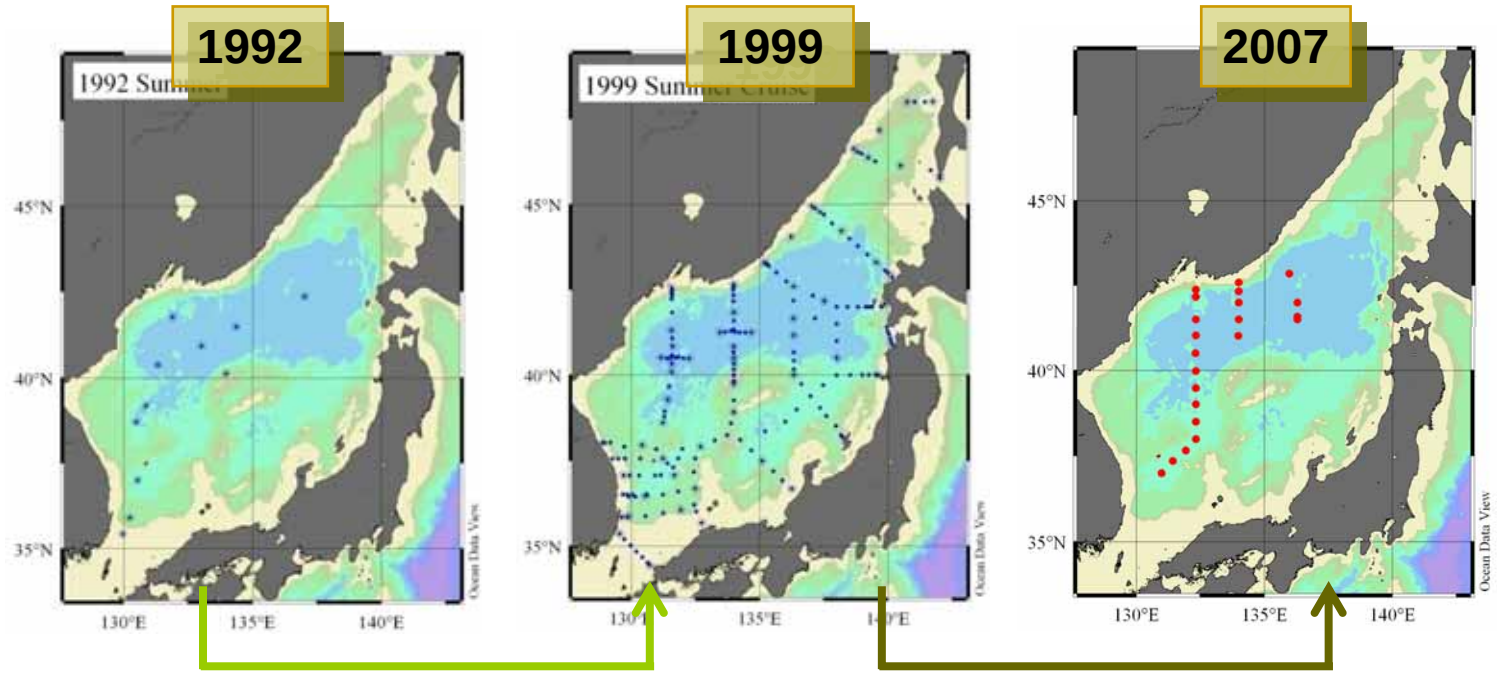
- **Specific Column Inventory (mol C m^{-2})**



- **Same latitude band** (mol C m^{-2})



CO_2 uptake rates



CO_2 uptake rates

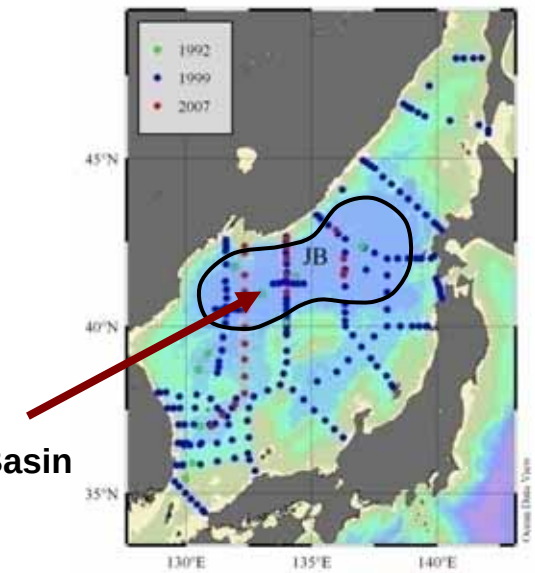
❖ **Isopycnal method** (***Peng et al.*, 1998, 2003**)

: comparing biologically corrected C_T data that were measured at different times on the same isopycnal horizon.

- $C_T = C_T^{meas} - C_T^{OM} - C_T^{CaCO3}$
- $NC_T = C_T/S \times 34.07$

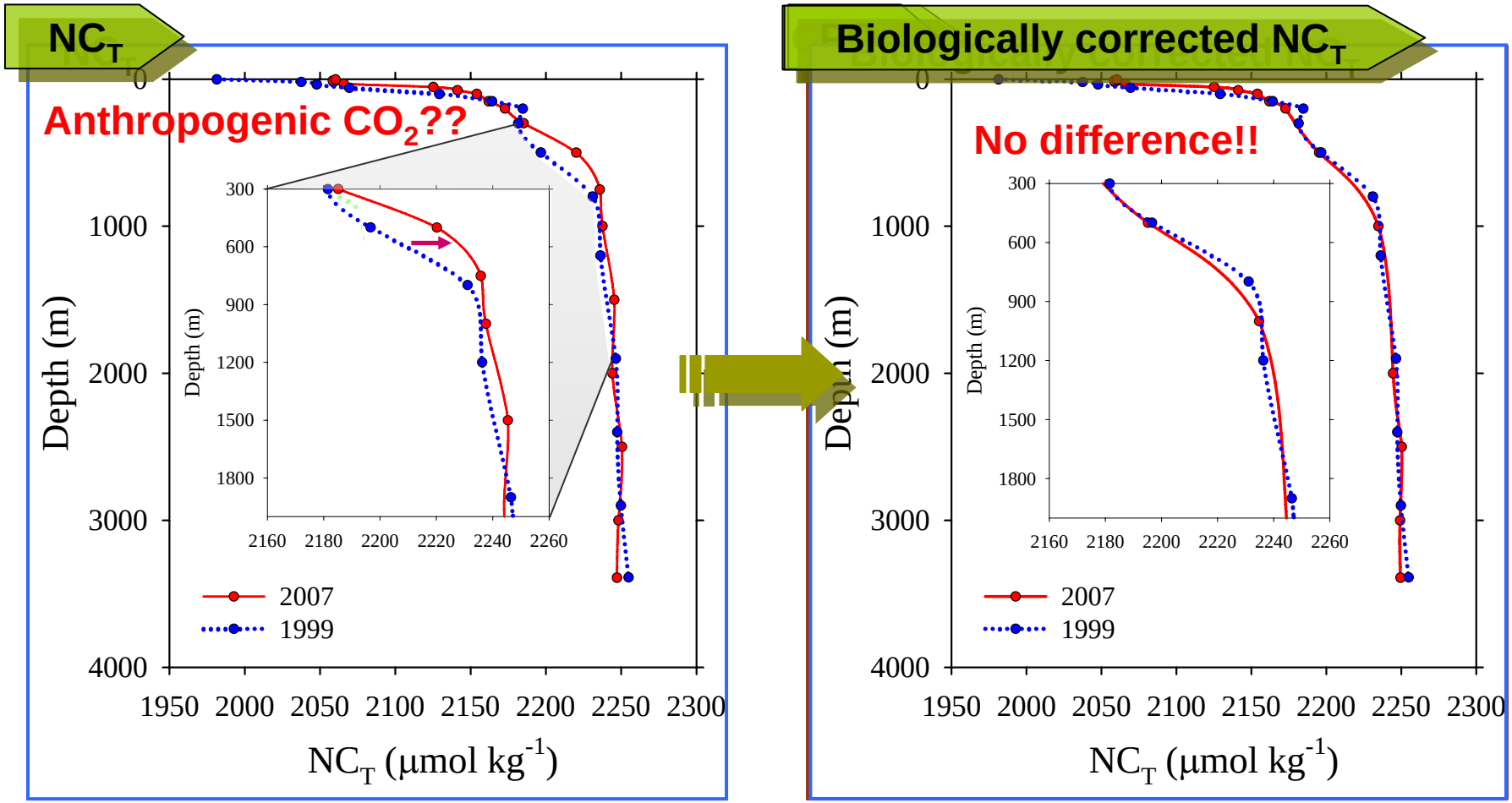
  (34.07 is the mean salinity)

- $\Delta TCO_2 = NC_{T(t+1)} - NC_{T(t)}$

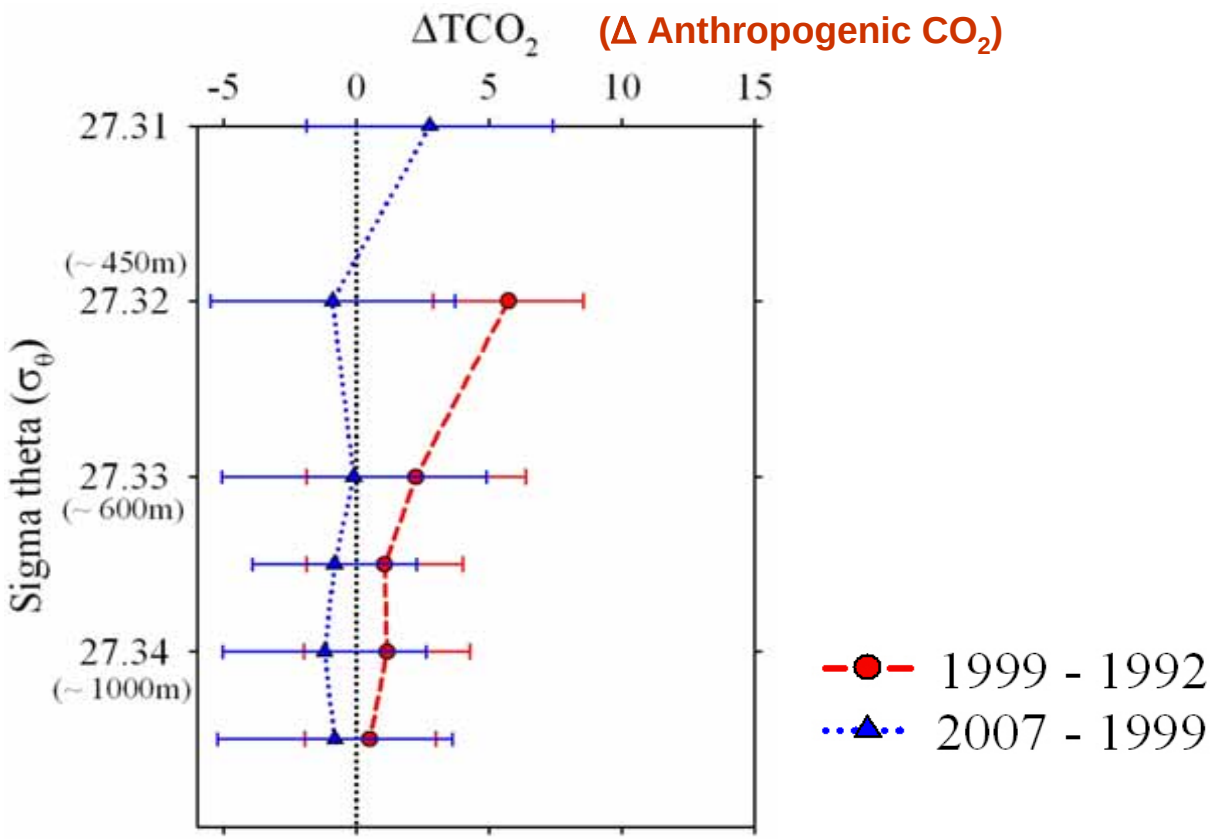


Japan Basin

C_T and O_2 Profiles between 1999 and 2007



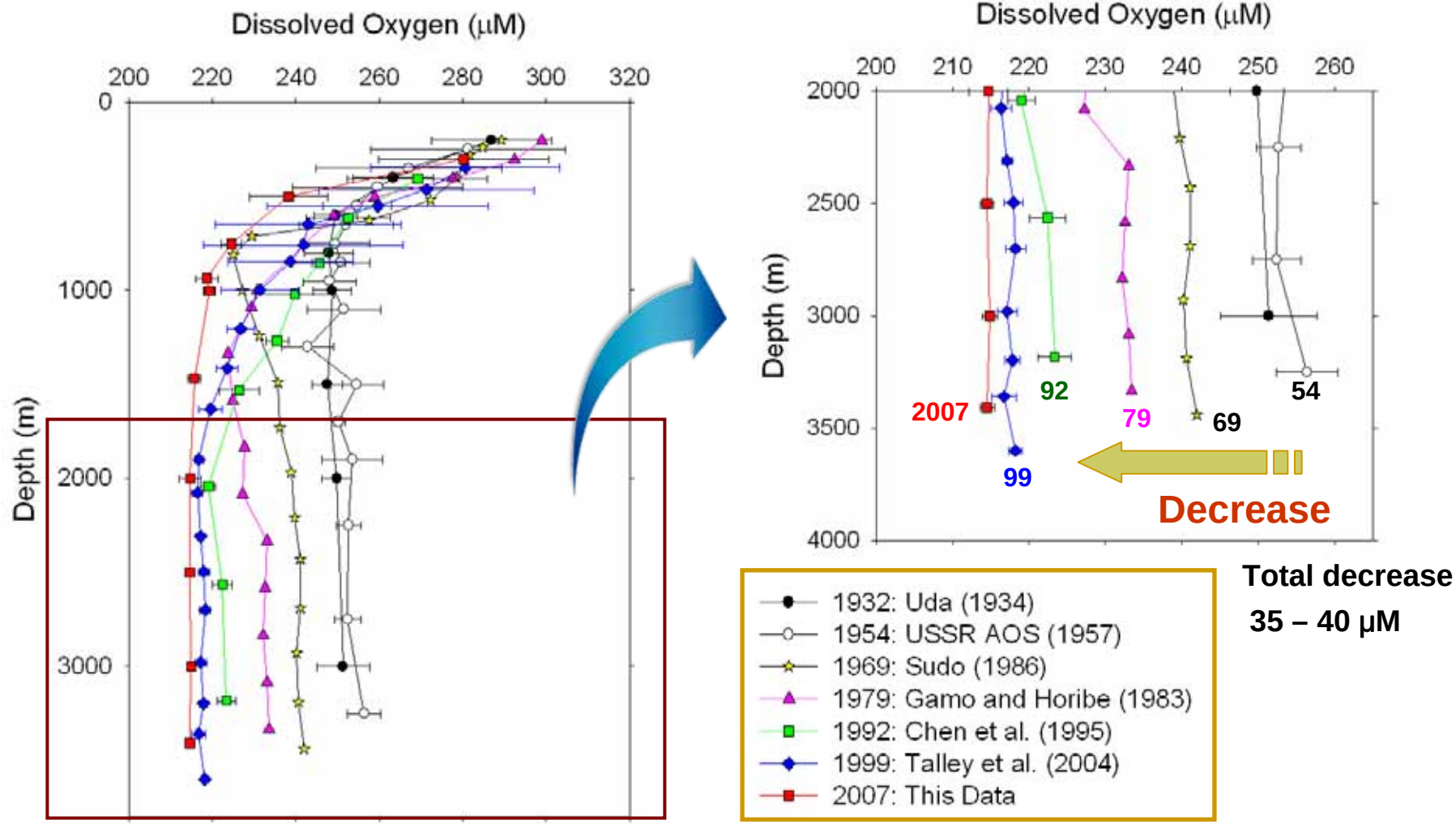
CO_2 uptake rates



- **1992–1999: 0.5 ± 0.3 mol m^{-2} yr^{-1}**
- **1999–2007: 0.0 ± 0.3 mol m^{-2} yr^{-1}**

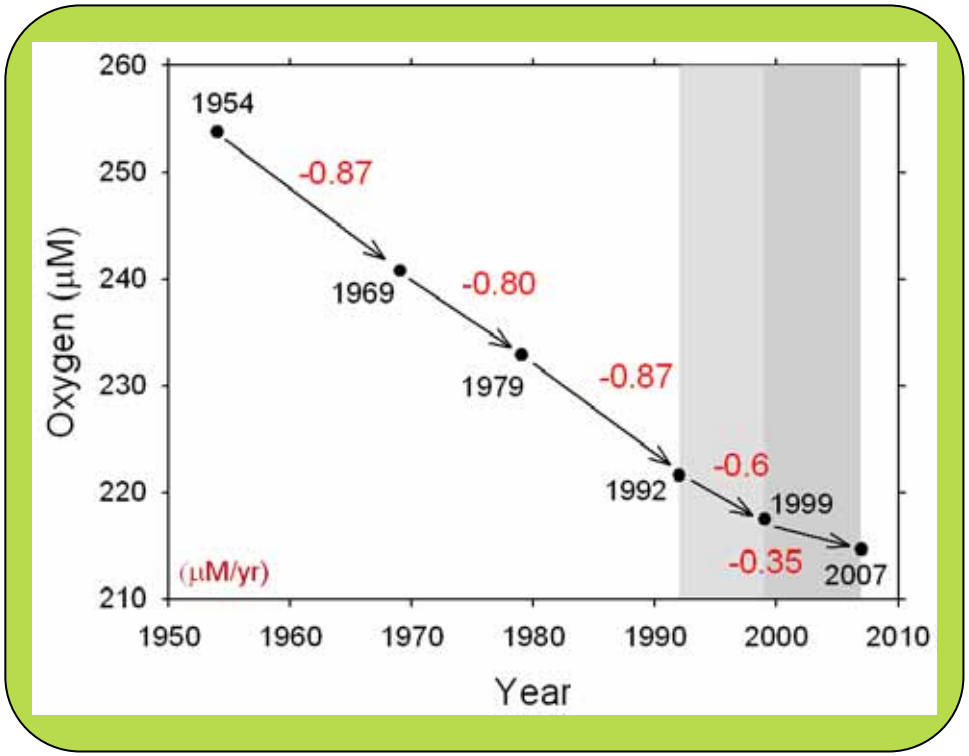
What causes the East Sea to be a weak sink of anthropogenic CO_2?

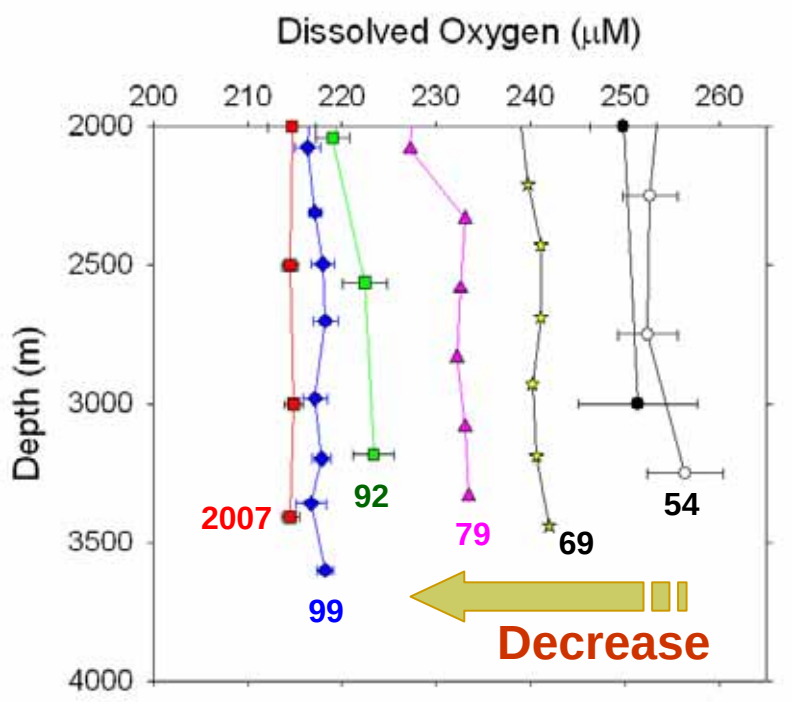
- **O_2 changes in the interior (indication of deep water ventilation)**



Total decrease
35 – 40 μM

O_2 changes in the deep water (>2000 m)



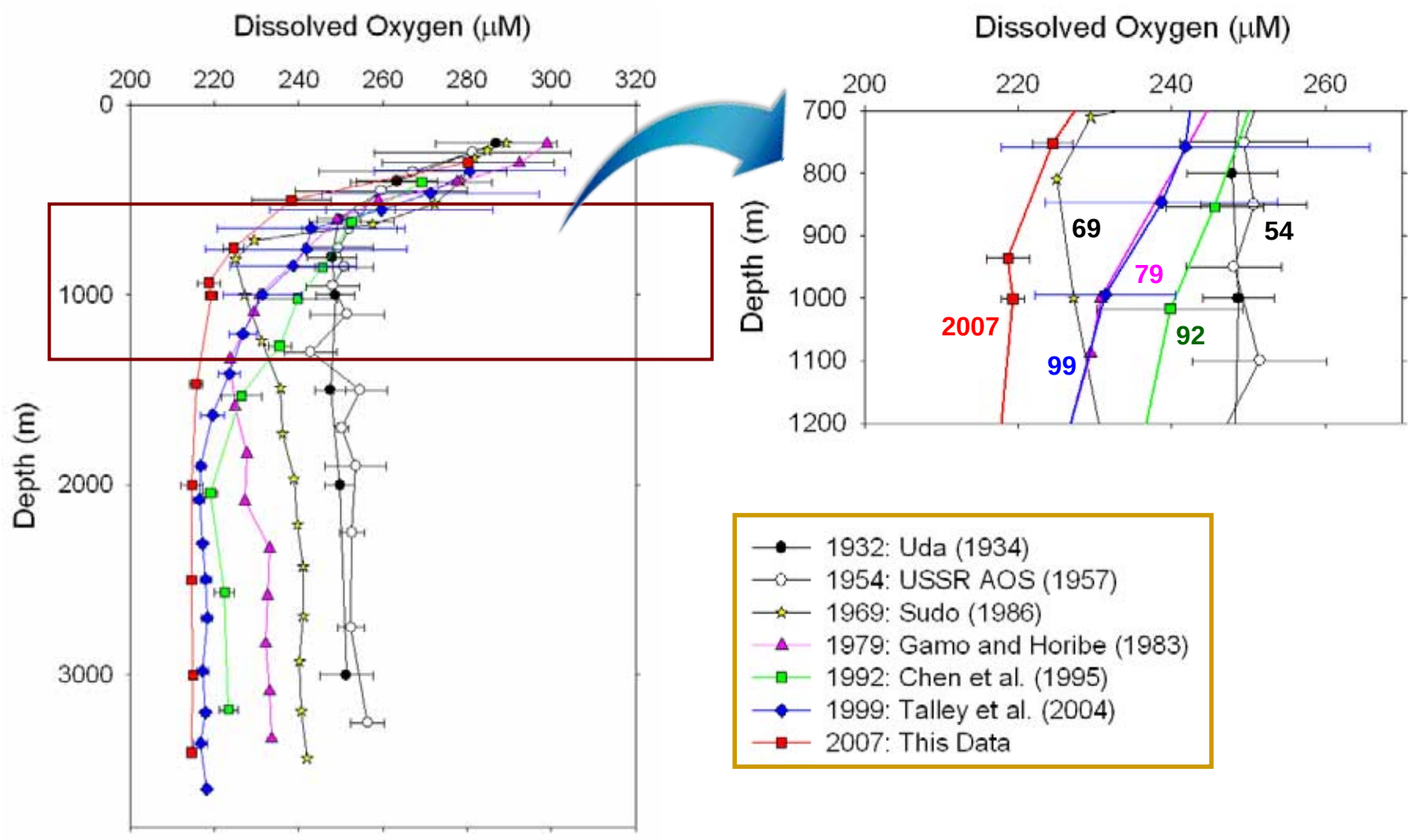


Total decrease
35 – 40 μM

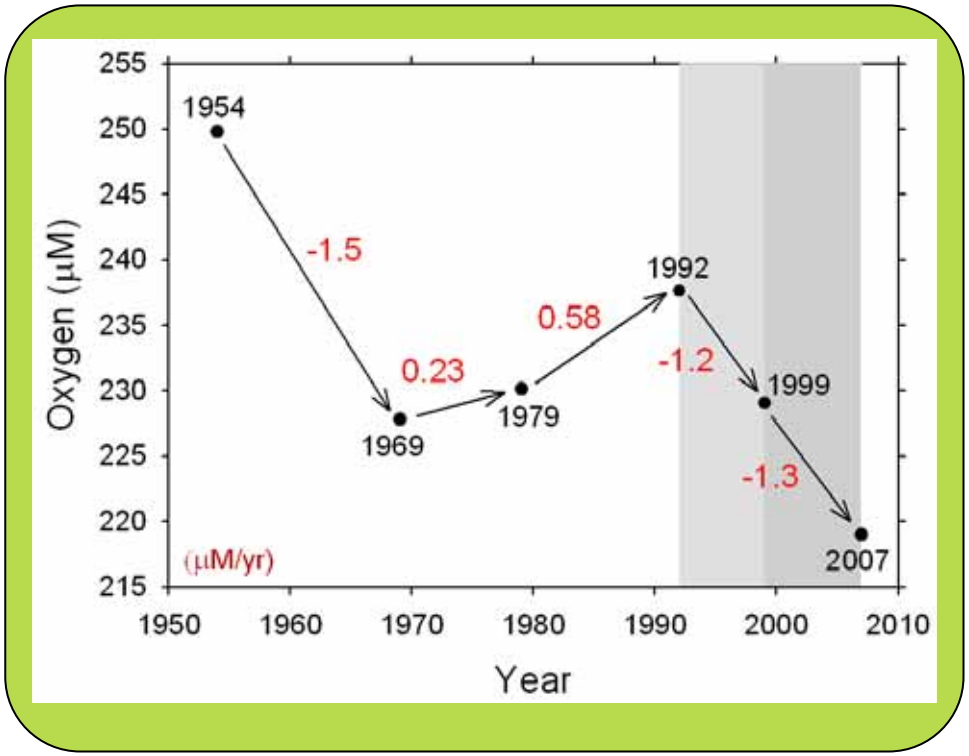
- 1932: Uda (1934)
- 1954: USSR AOS (1957)
- 1969: Sudo (1986)
- 1979: Gamo and Horibe (1983)
- 1992: Chen et al. (1995)
- 1999: Talley et al. (2004)
- 2007: This Data

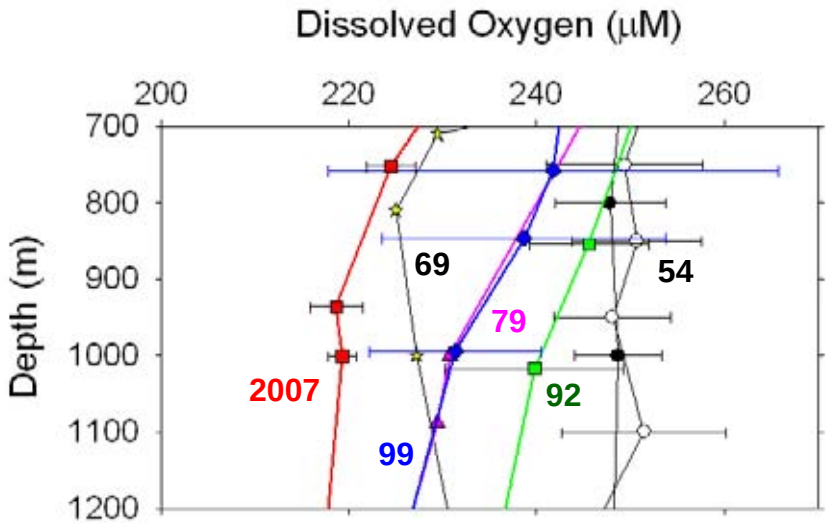
➢ **Weakening of ventilation since 1950**

O_2 changes in the intermediate water (600–1200 m)



O_2 changes in the intermediate water (600–1200m)





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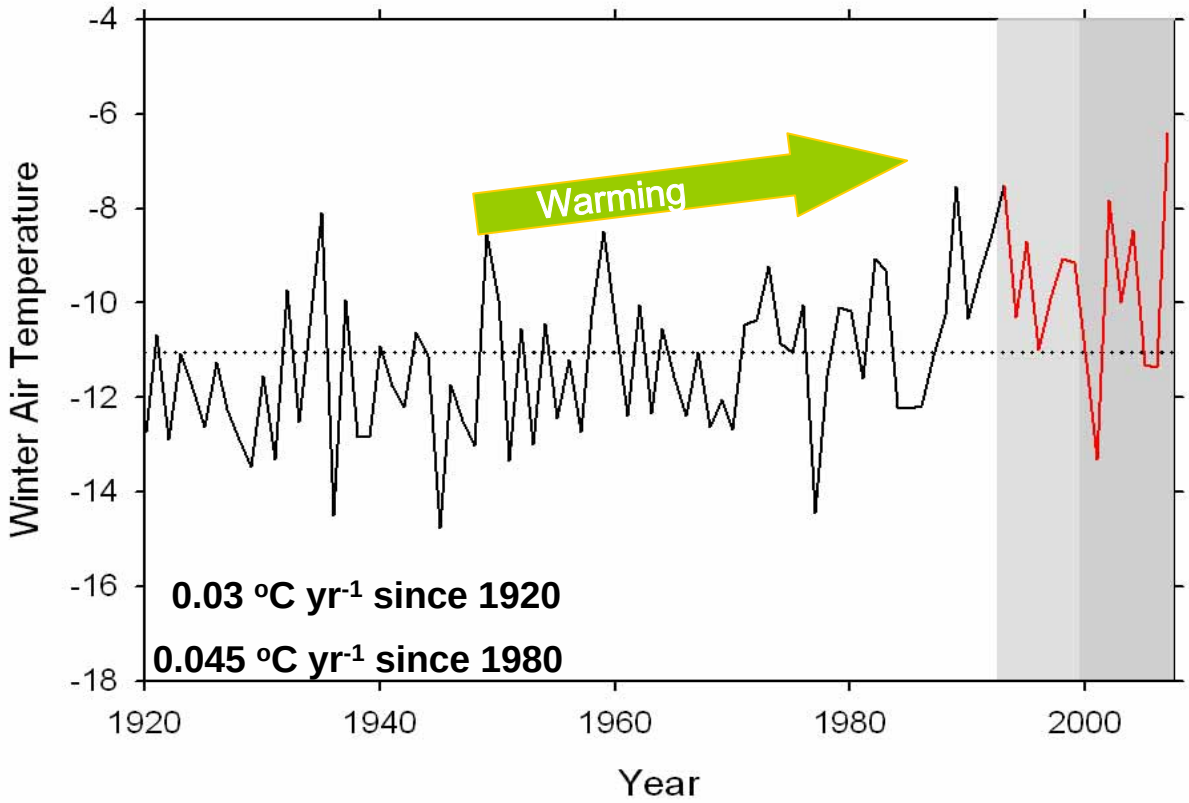
- 1992: Chen et al. (1995)
- 1999: Talley et al. (2004)
- 2007: This Data

- Increase of ventilation between 1970–1990.
- Weakening of ventilation between 1990–2007.

What causes ventilation to decrease in the East/Japan Sea?

- **Winter air temperature at Vladivostok**

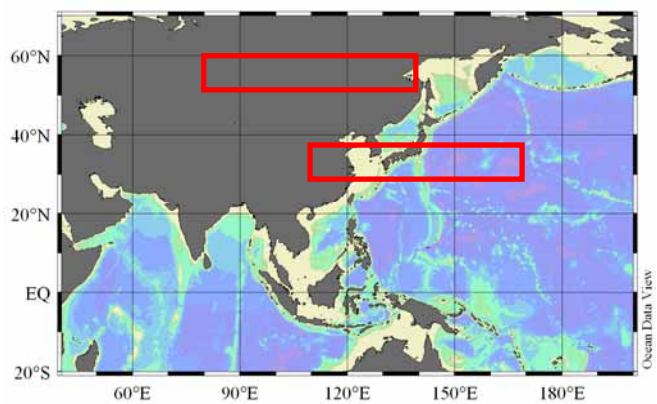


<From Global Historical Climatology Network>
(GHCN-monthly version 2)

(http://www.ncdc.noaa.gov/oa/climate/ghcn-monthly/index.php)

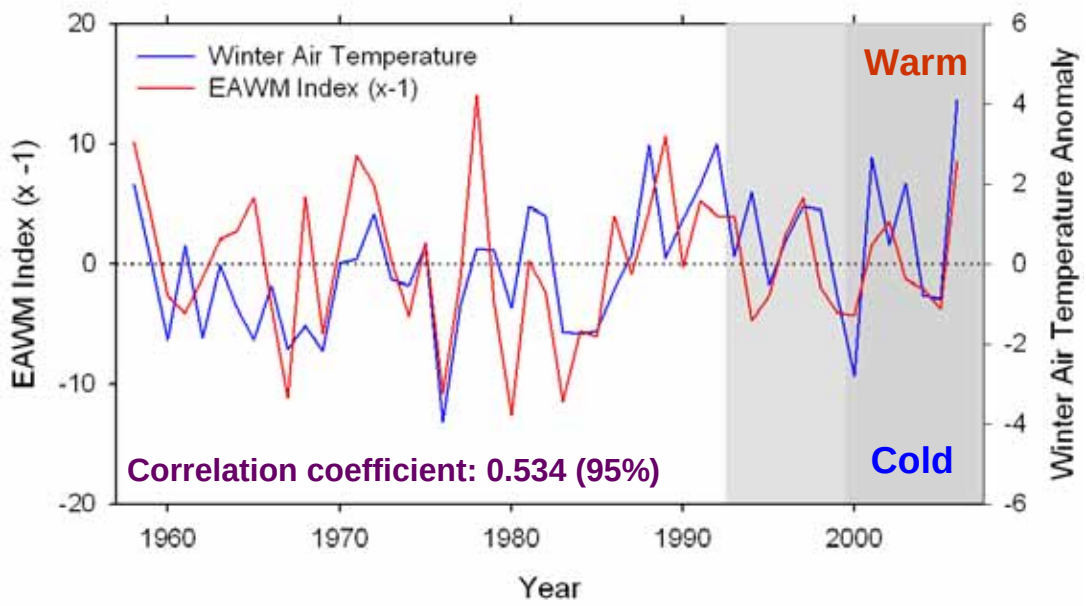
East Asian Winter Monsoon Index

(Jhun & Lee, 2004, J. Climate)



- EAWMI
  = U_{300} (27.5-37.5ºN, 110-170ºE)
  – U_{300} (50-60ºN, 80-140ºE)

➢ **Short-term (~5 years) variability in winter air temperature at Vladivostok is controlled by the East Asian Winter Monsoon**



Conclusions

- Little uptake of anthropogenic CO_2 between 1999 and 2007 by the East/Japan Sea.
- The considerable weakening of deep and intermediate water ventilation might be responsible.
- The weakening of ventilation may be directly related to recent winter air warming (winter surface warming) near Vladivostok