Decadal Trend of Carbon Dioxide and Ocean Acidification in the surface water of the Ulleung Basin, East/Japan Sea

Jae-Yeon Kim[1], Dong-Jin Kang[2], Tonsup Lee[1], Kyung-Ryul Kim[3]

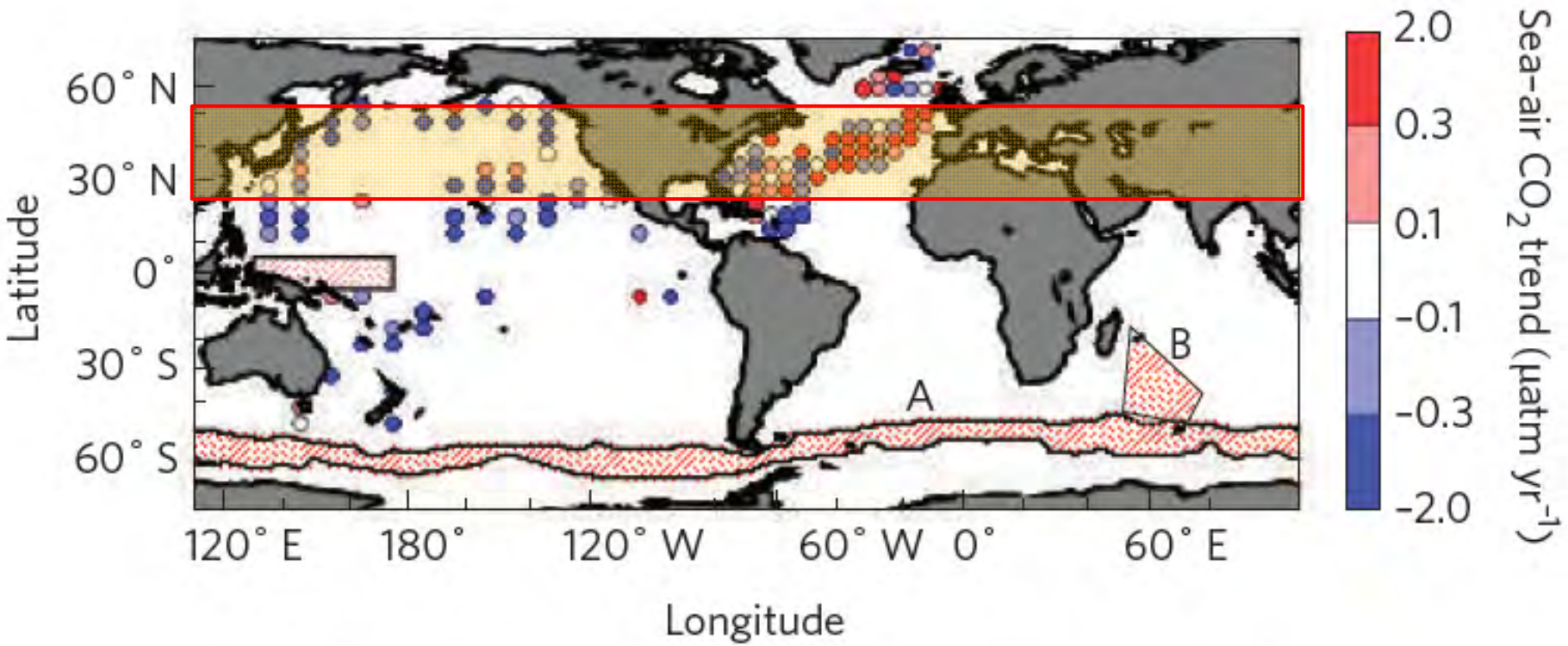
[1] Department of Oceanography, Pusan National University, Korea

[2] Korea Ocean Research and Development Institute, Korea

[3] School of Earth & Environmental Sciences/Research Institute of Oceanography, Seoul National University, Korea

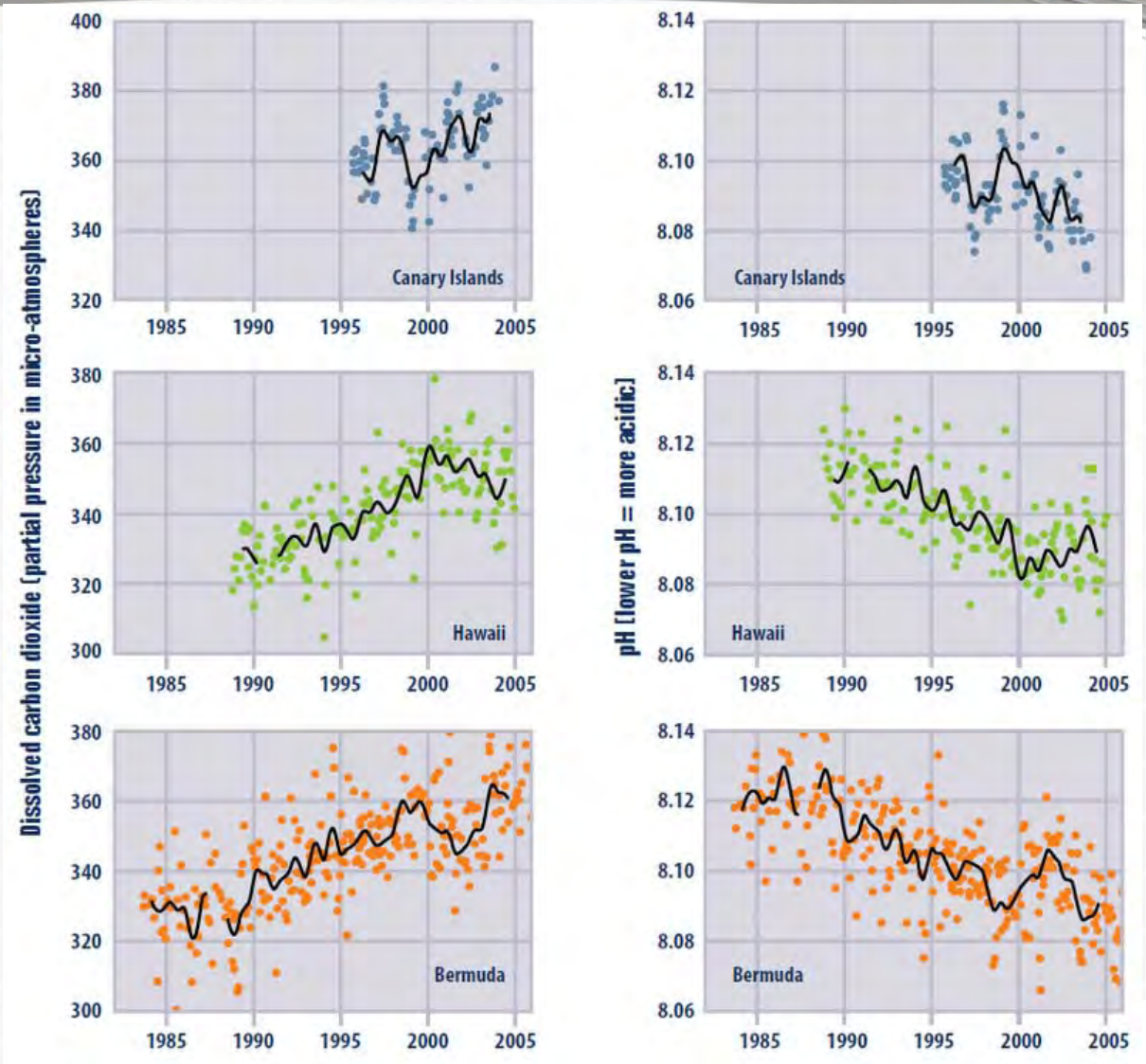
Contents

Trends in the observed partial pressure of CO_2 for ocean minus air, for 1981-2007



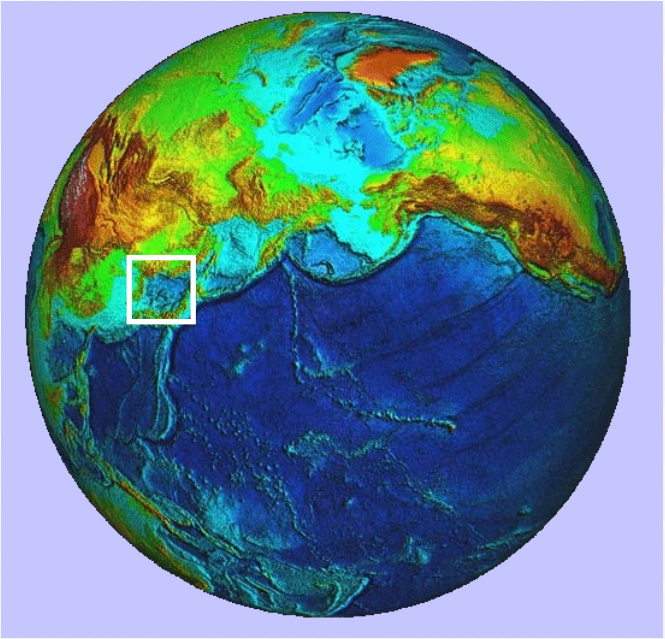
Le Quéré et al. 2009

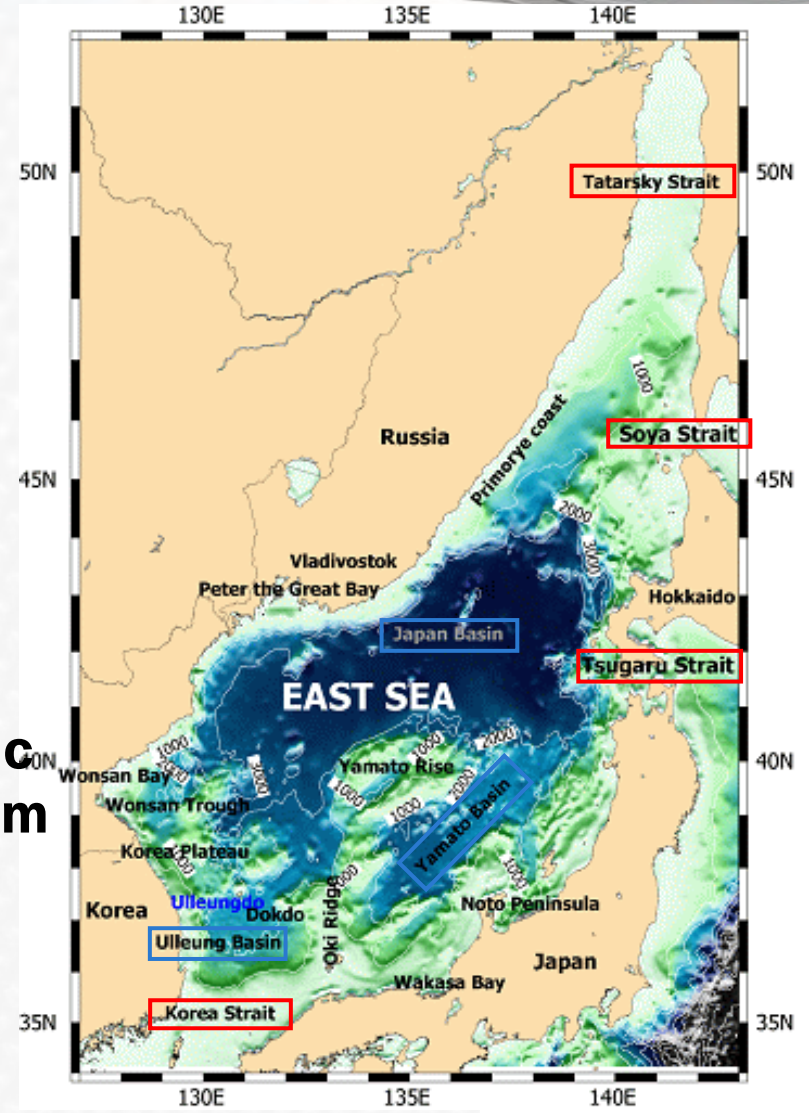
Change in surface ocean pCO_2 and pH 1983–2005



Based on Gonzalez-Dávila et al. 2003; Dore et al. 2003; Bates et al. 2002; Gruber et al. 2002; IPCC 2007

The East/Japan Sea

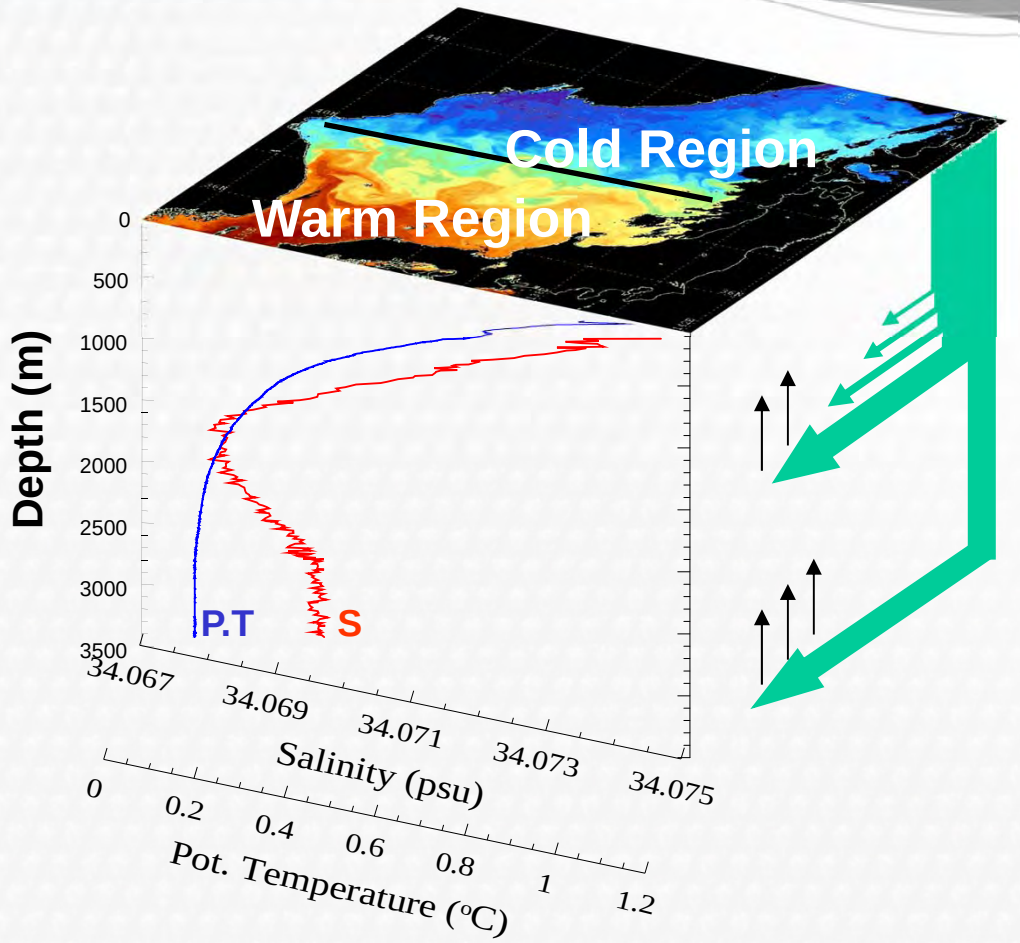




A marginal sea of the Pacific
3 basins deeper than 2000 m
Max sill depth: ~150 m

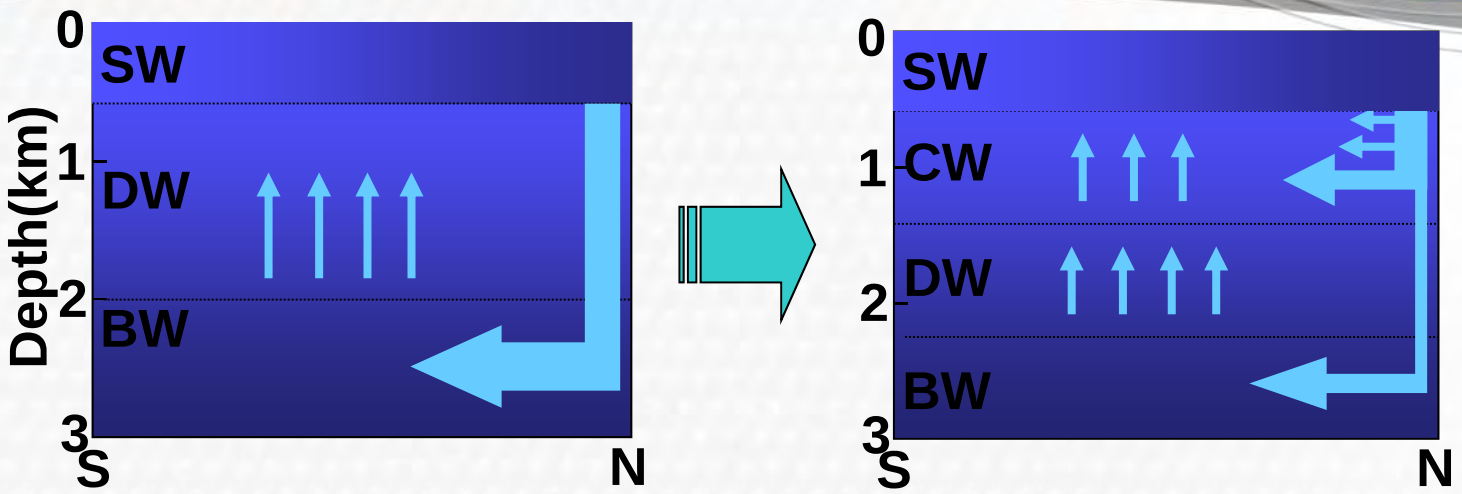
Semi-isolated basin

The East/Japan Sea: A Miniature Ocean



- **Deep convection**
- **Thermohaline circulation**
- **Double-Gyre circulation**
- **Sub-polar front**
- **Mesoscale eddies**
- **Upwelling**

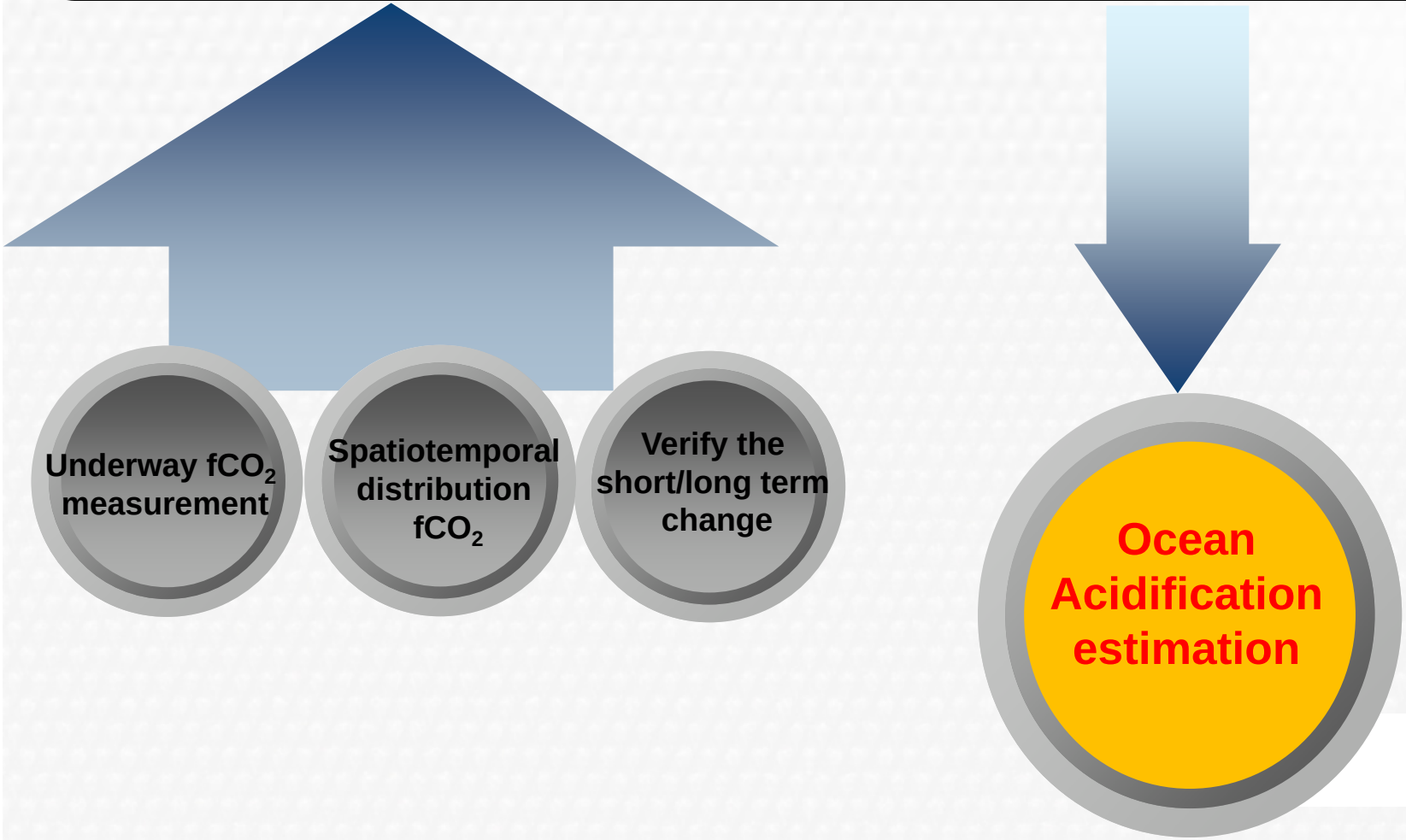
Role of the East/Japan Sea



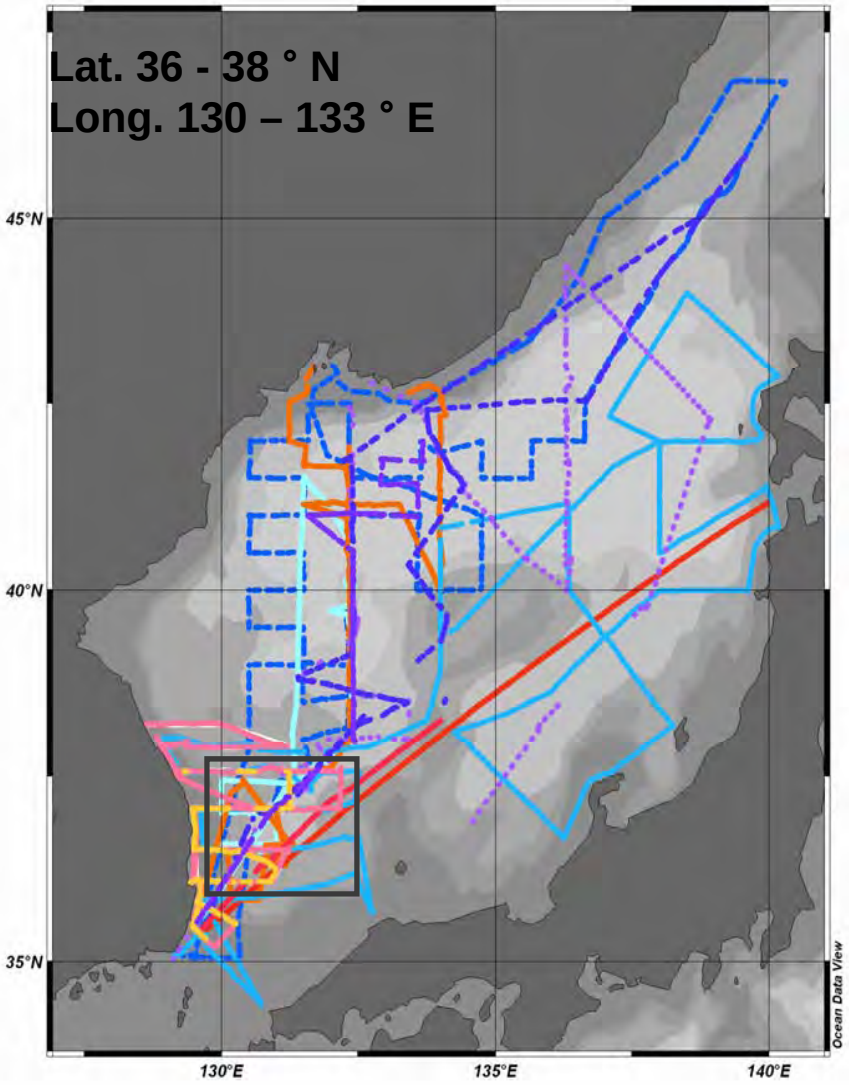
- Oceans are now in a state of change.
- Shift in conveyor belt system in the East Sea shows a resemblance to what is supposed to happen in the global ocean conveyor belt associated with global warming.
- Behavior of the East/Japan Sea is needed to look at from a global point of view.

Purpose of this Study

Decadal change of CO_2 in the Ulleung Basin, East/Japan Sea

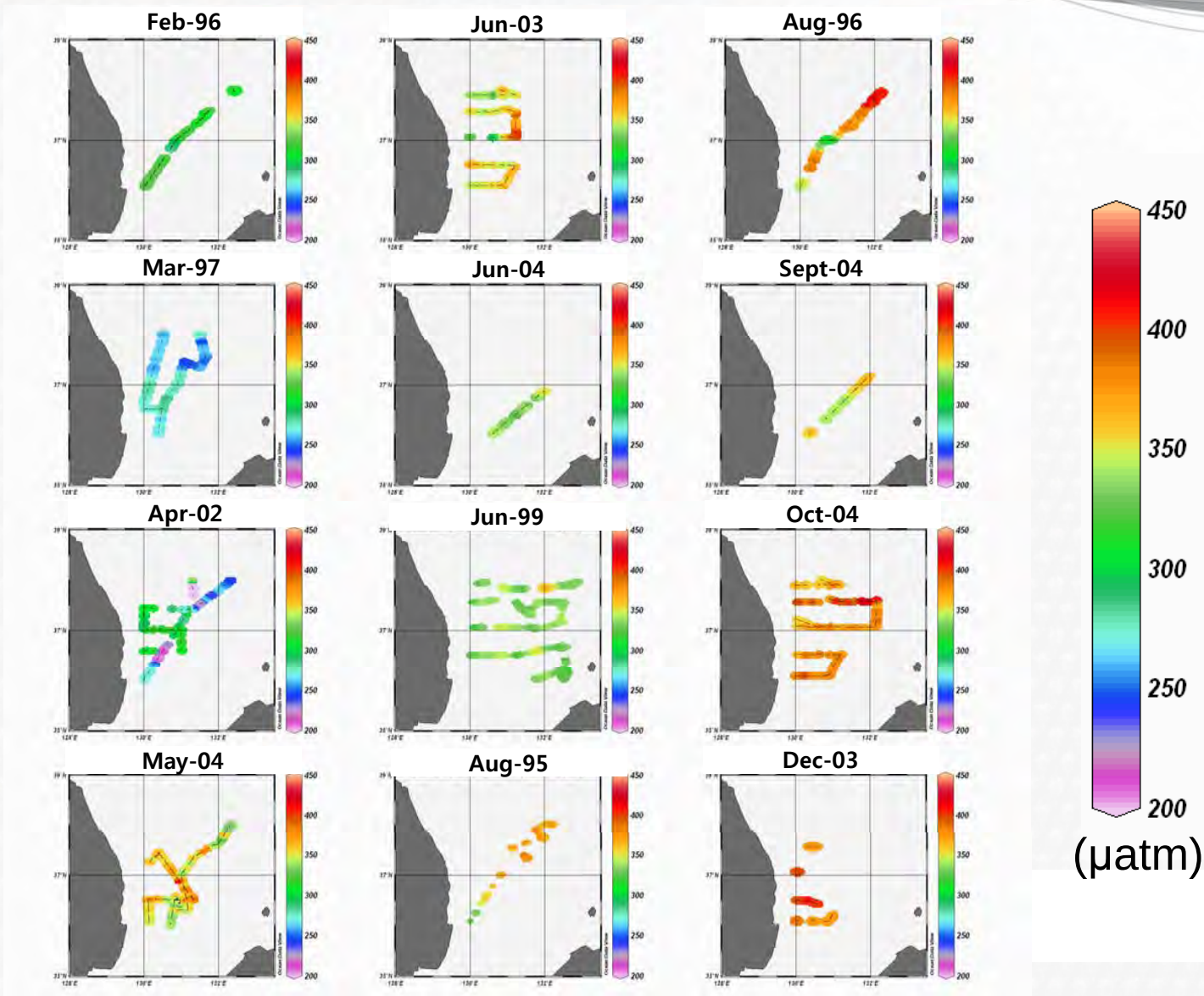


Underway measurement of CO_2 in the Ulleung Basin, East/Japan Sea

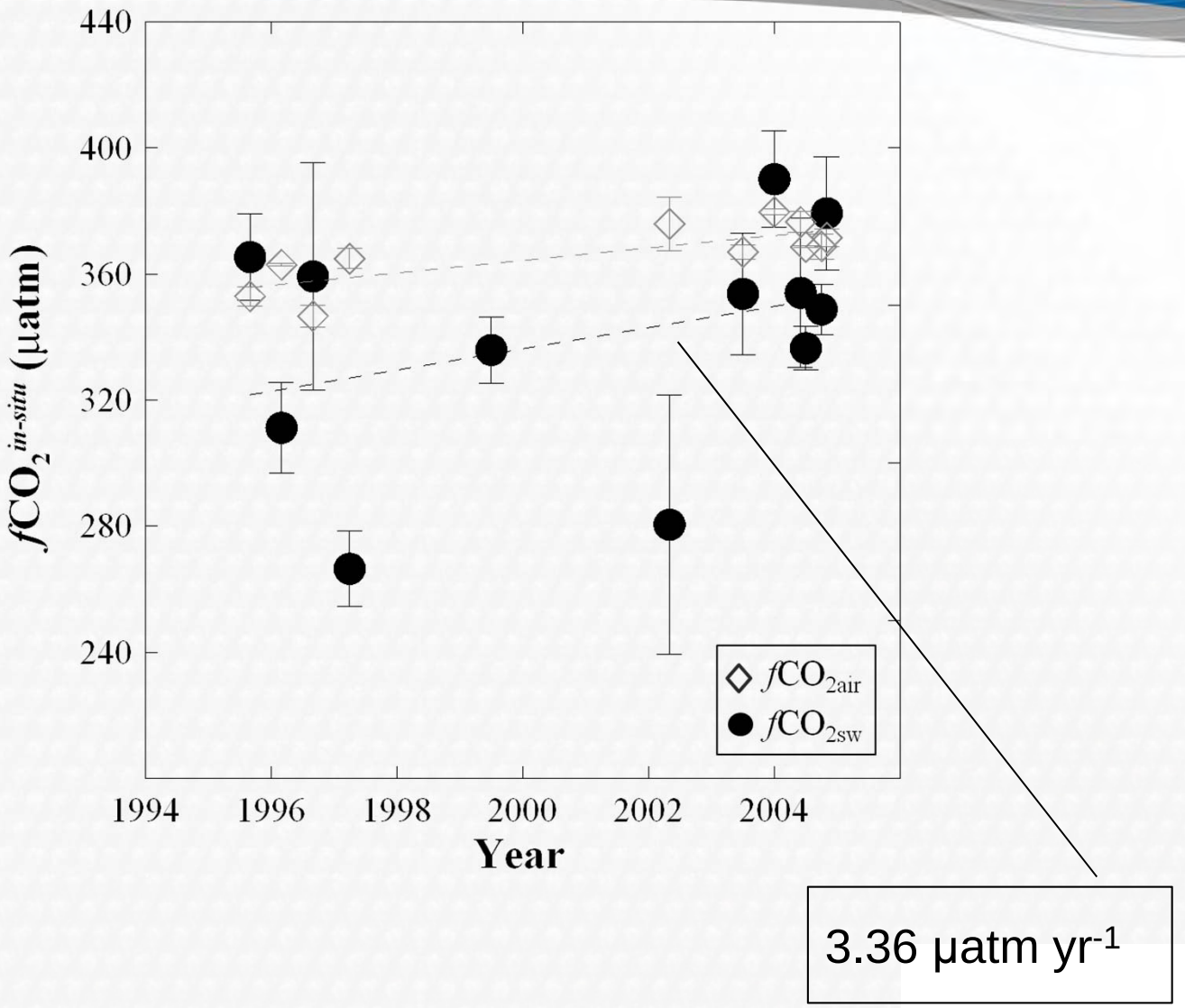


Time	Research Vessel
6-7 Aug. 1995	R/V Professor Khromov
23-24 Feb. 1996	R/V Parvel Gordienko
31Jul.-10 Aug. 1996	R/V Professor Khromov
19 Mar.–7 Apr. 1997	R/V Parvel Gordienko
25 Jun. - 1 Jul. 1999	R/V Roger Revelle
12-19 Apr. 2002	R/V Professor Gargarinsky
9-14 Jun. 2003	R/V Tamgu-5
12-22 Dec. 2003	R/V Tamgu-5
6-19 May 2004	R/V Akademik Labrantiev
10 -11 Jun. 2004	R/V Tamgu-1
14-15 Sep. 2004	R/V Tamgu-1
5-29 Oct. 2004	R/V Tamgu-5

Observed fCO_{2sw}



Decadal trend in fCO_{2sw} & fCO_{2air}



Corrected fCO_2 monthly variation for the reference year of 1995

$$fCO_2^{1995} = fCO_2^{\,in\text{-}situ} - 3.36 \times (Year - 1995)$$

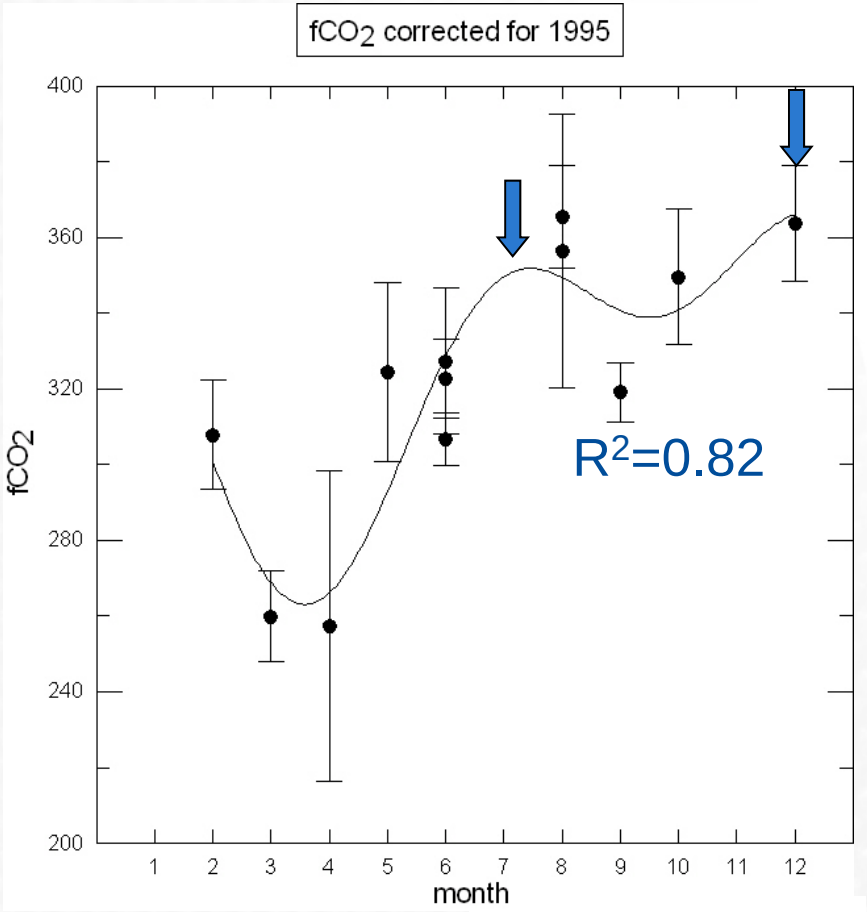
Harmonic function analysis :

$$fCO_2^{1995}(t) = c_0 + c_1\sin(2\pi t) + c_2\cos(2\pi t)$$

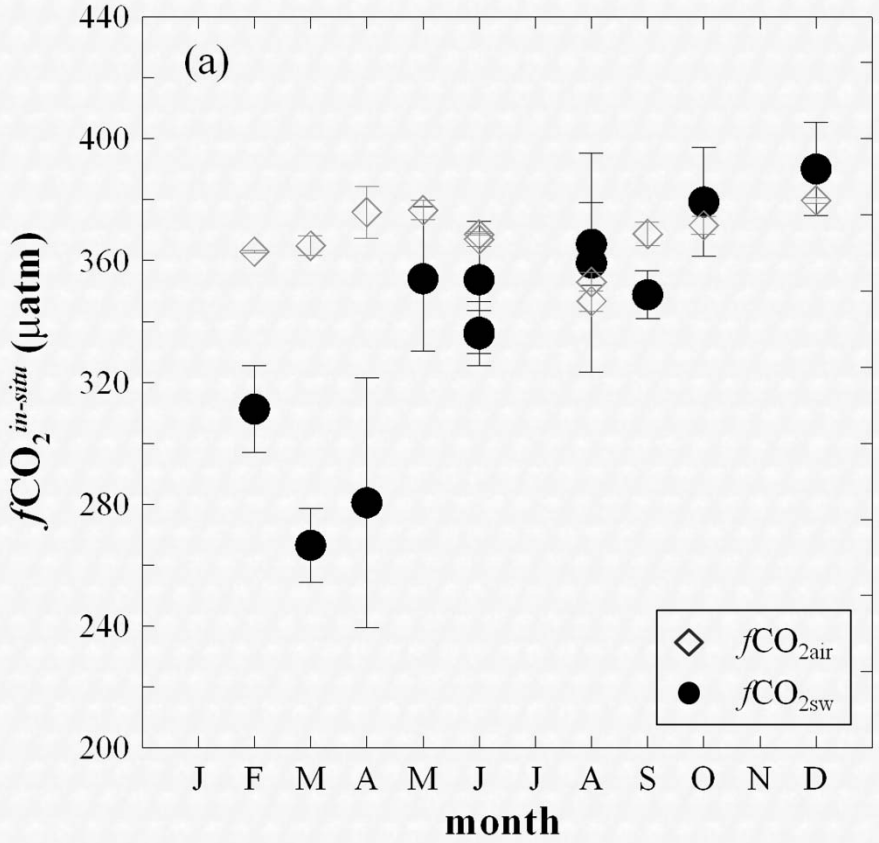
$$+ c_3\sin(\pi t) + c_4\cos(2\pi t)$$

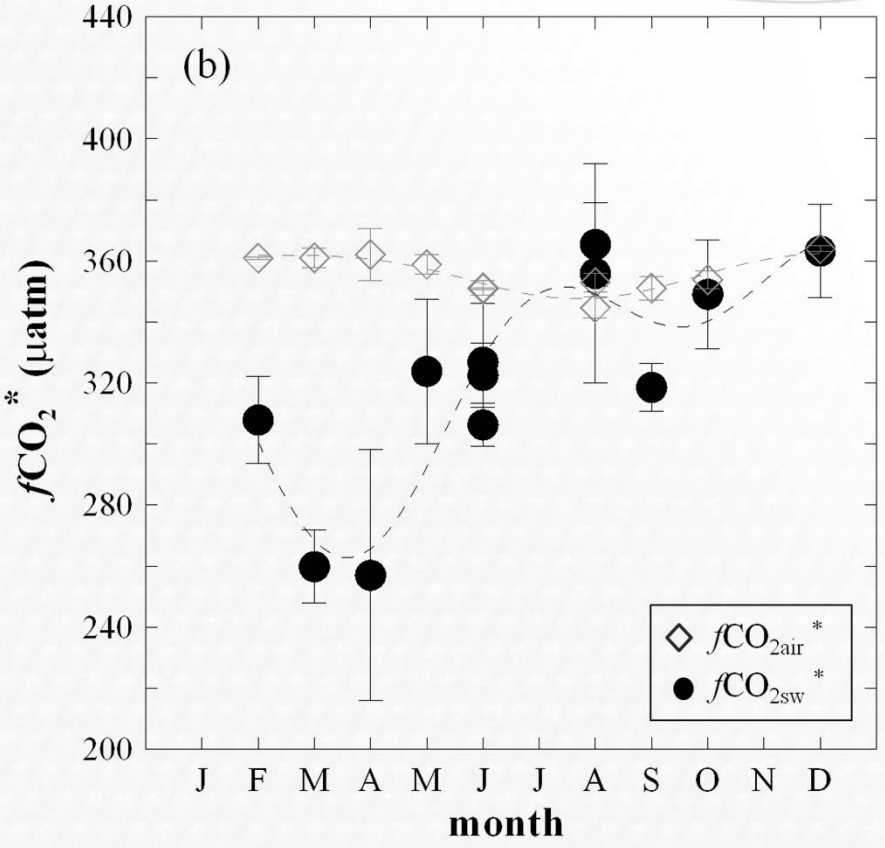
(Nojiri et al, 1999, Zeng et al, 2002)

$$fCO_2^{\,*} = fCO_2^{1995}(t) + 3.36 \times (Year - 1995)$$



Monthly variations in $fCO_2^{in\text{-}situ}$ & fCO_2^*





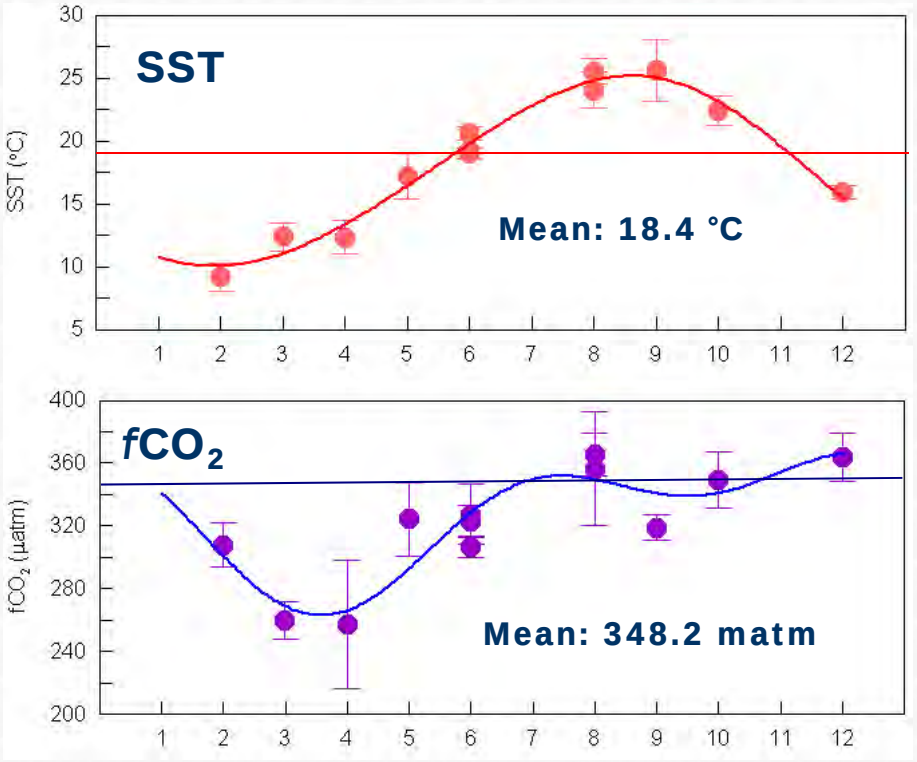
Thermal and non-thermal forcing on surface fCO_2

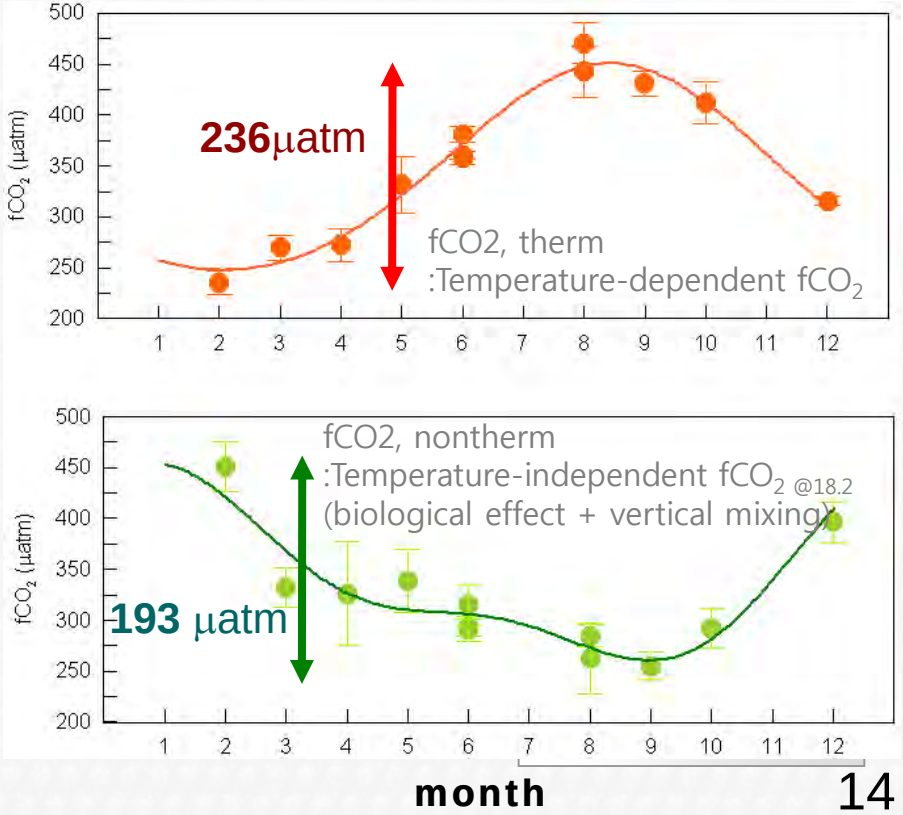
$$fCO_{2\ nontherm} = fCO_{2\ obs} \times e^{0.0423\ (Tmean-Tobs)}$$

$$fCO_{2\ therm} = fCO_{2\ mean} \times e^{0.0423\ (Tobs-Tmean)}$$

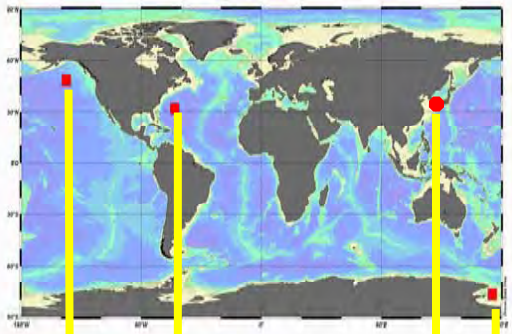
Takahashi et al., 2002

Ulleung Basin



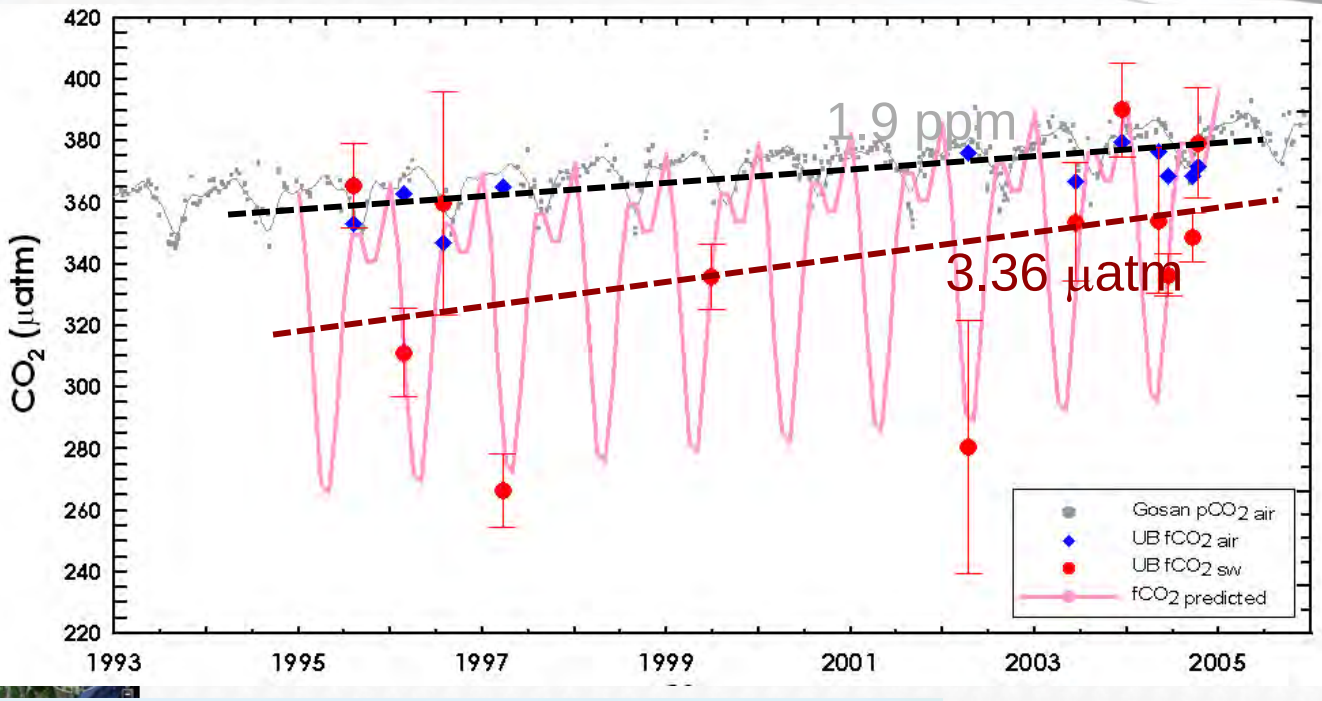


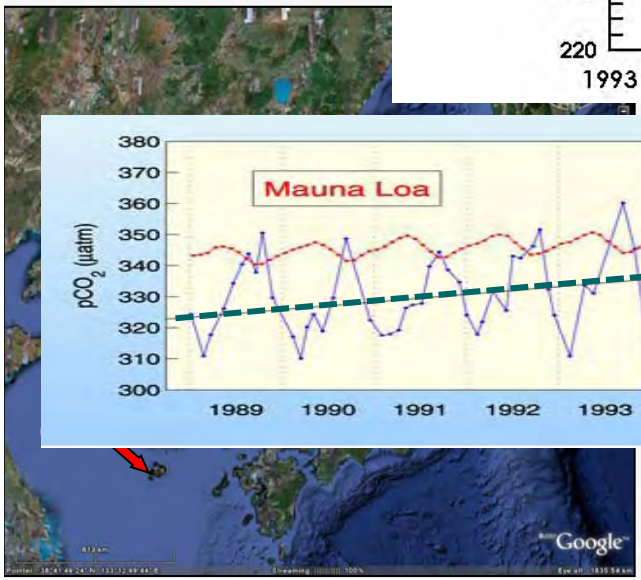
Comparison with other sites



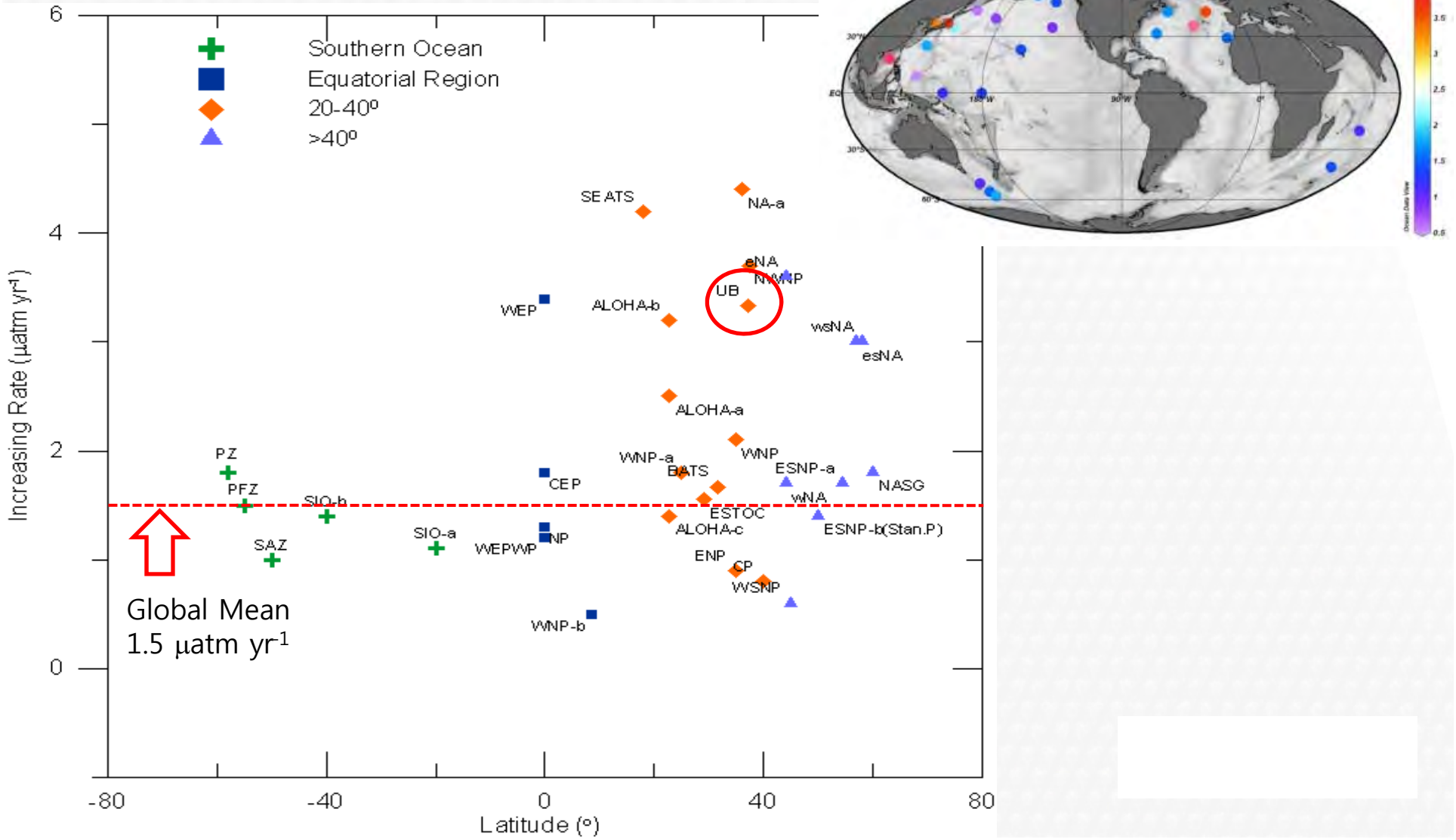
	Thermal Effect [μatm]	Non-Thermal Effect [μatm]	T/N-T	location
Ulleung Basin	236	193	1.2	36-38 ° N 30-133 ° E
BATs	150	55	2.7	32° 50' N 64 ° 10'w
Ross Sea	5	260	0.02	76 ° 30'S 169E-177 ° W
Station "P"	100	115	0.9	50 °N 145 °W

Long-Term Variability of fCO_2

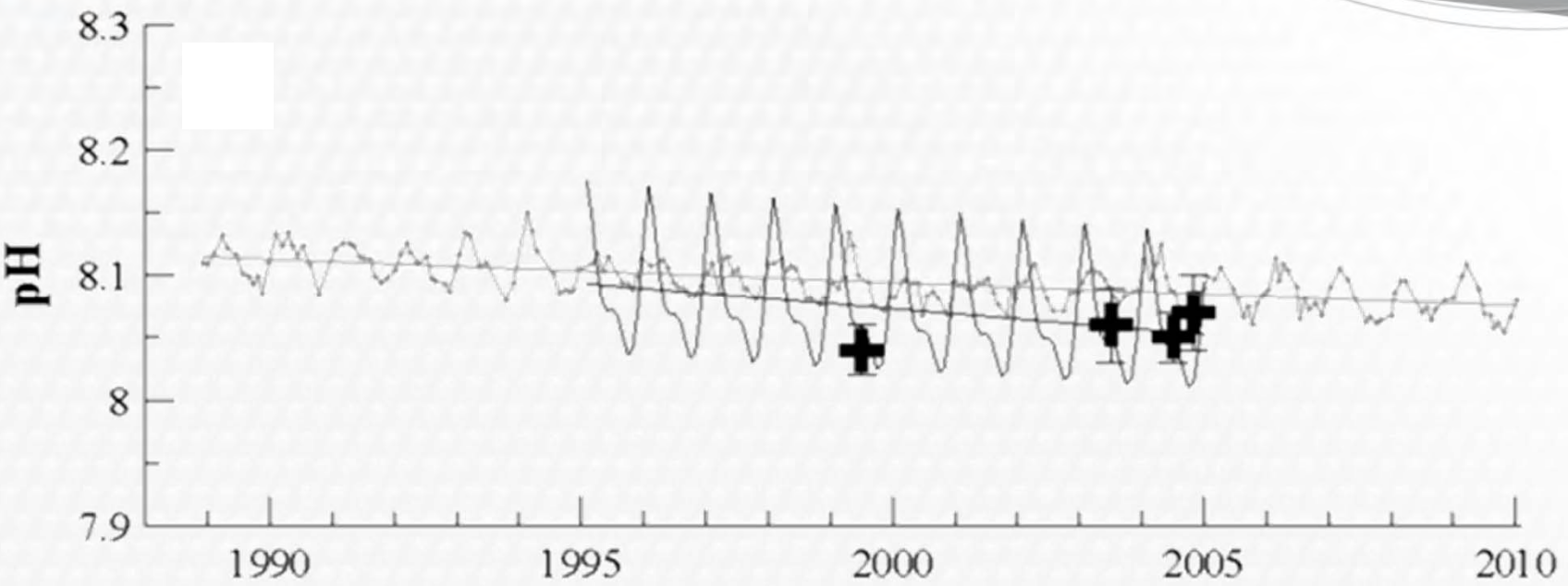




(Dore et al., 2003, Keeling et al., 2004)


Southern Ocean
Equatorial Region
20-40º
>40º
SEATS
NA-a
eNA
NWNP
UB
WEP
ALOHA-b
wsNA
esNA
ALOHA-a
WNP
WNP-a
BATS
ESNP-a
NASG
PZ
PFZ
SIO-b
CEP
wNA
ESTOC
ALOHA-c
ESNP-b(Stan.P)
SIO-a
SAZ
WEPWP
NP
ENP
CP
WSNP
WNP-b
Global Mean
1.5 µatm yr-1
Increasing Rate (µatm yr-1)
Latitude (°)
6
4
2
0
-80
-40
0
40
80

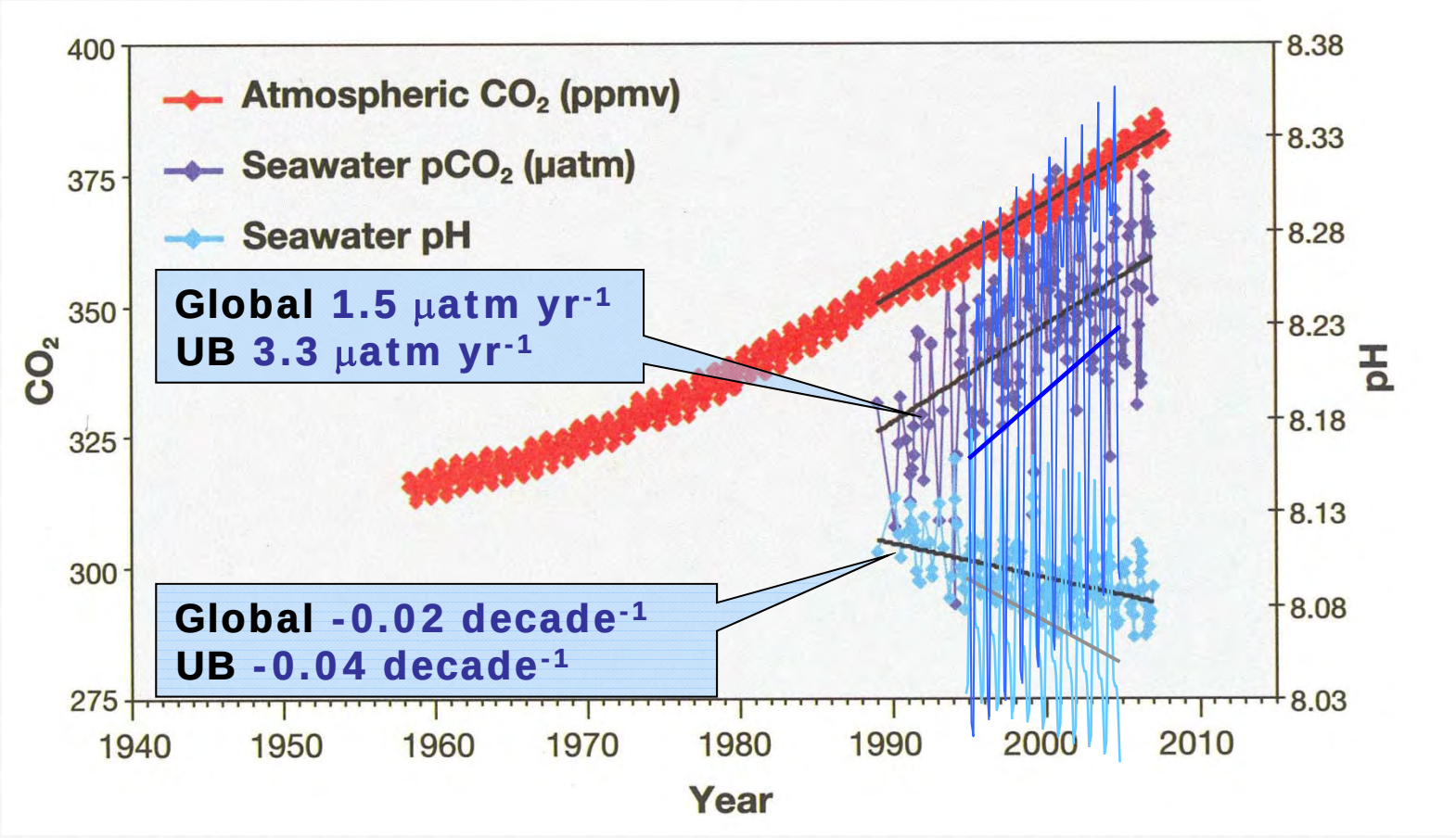
Long-Term Variability of pH



Calculated with CO2SYS
Assume that TA is constant (2266±17 μeq kg^{-1})

Good agreement with Measured values (r^2 = 0.8)

CO_2 and pH time series in the UB vs. Global



Summary

- Surface CO_2 concentration in the East Sea (Ulleung Basin) has been increasing (~3.4 μatm yr^{-1}).
- Surface water of Ulleung Basin is acidifying rapidly.

  Ulleung Basin 0.04 pH unit/decade

  Global ocean 0.02 pH unit/decad

Acknowledgements

Ministry of Land, Transport & Maritime Affairs, Korea
East Asian Seas Time-series I (EAST-1)

National Fisheries Research & Development Institute, Korea
Drs. Hee-Dong Jung, Yeong-Sang Suh, Yong-Hwa Lee,
In-Sung Han, Ki-Tak Sung

Pacific Oceanological Institute, Russia
Drs. V. Lobanov, P. Tishchenko, R. Chichkin

Far Eastern Hydrometeorological Research Institute, Russia
Dr. Y. Volkov

Circulation Research of East Asian Marginal Sea (CREAMS)
Profs. M. Takematsu, Kuh Kim

Thank you!