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Interannual variability of winter oceanic CO_2 along 137°E in the western North Pacific

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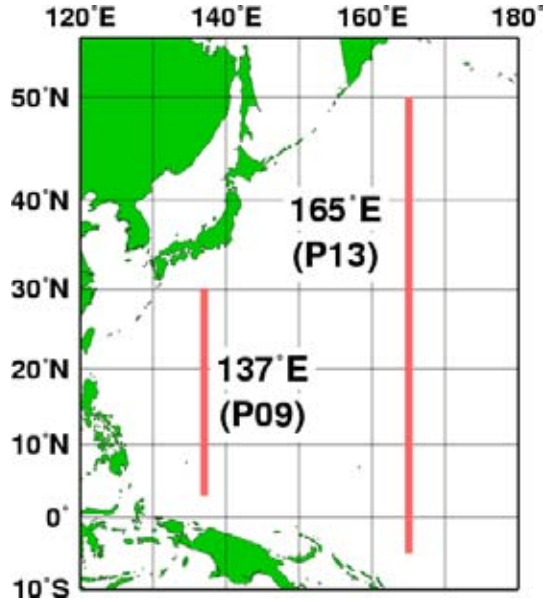
JMA's observation of CO_2



pCO_2

- **Repeat lines**
  - 137°E (P09, 1981~) and 165°E (P13, 1996~)
- **Research vessels**
  - Ryofu Maru and Keifu Maru
- **Frequency**
  - 137°E (P09): Once (1981~1989), Twice (1990~2000) and 4 times (2001~2007) a year
  - 165°E (P13): Once (1996~2000) or Twice (2001~2007) a year

DIC (dissolved inorganic carbon)

Depth: 0 ~ 2000m

Interval: 137°E (5 °), 165°E (various)

Frequency: 137°E (4 times a year), 165°E (Once a year)

other parameters: temperature, salinity, oxygen, nutrients, chlorophyll a etc.

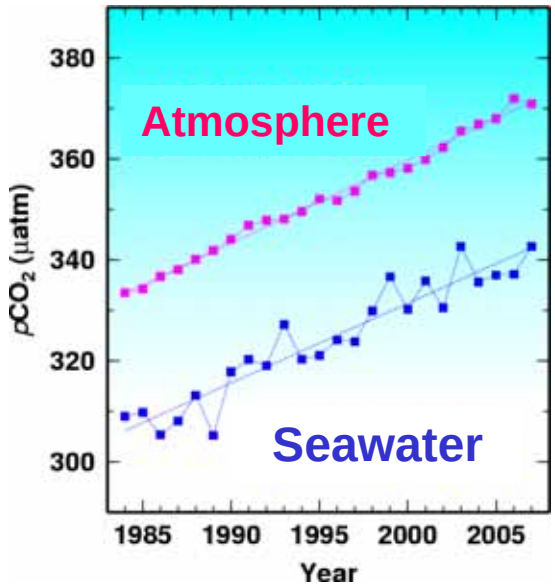
Surface seawater pCO_2 along 137°E in Winter

Previous studies

- Seawater pCO_2 increase was found (Inoue et al. 1995)
- Controlling factors of the interannual variations were discussed (Midorikawa et al., 2006)
  - El Niño Southern Oscillation (ENSO) in the equatorial regions
  - The entrainment process in the northern part of subtropics

< Possible Factors >

- Thermodynamical factors
- Other physical and biogeochemical factors



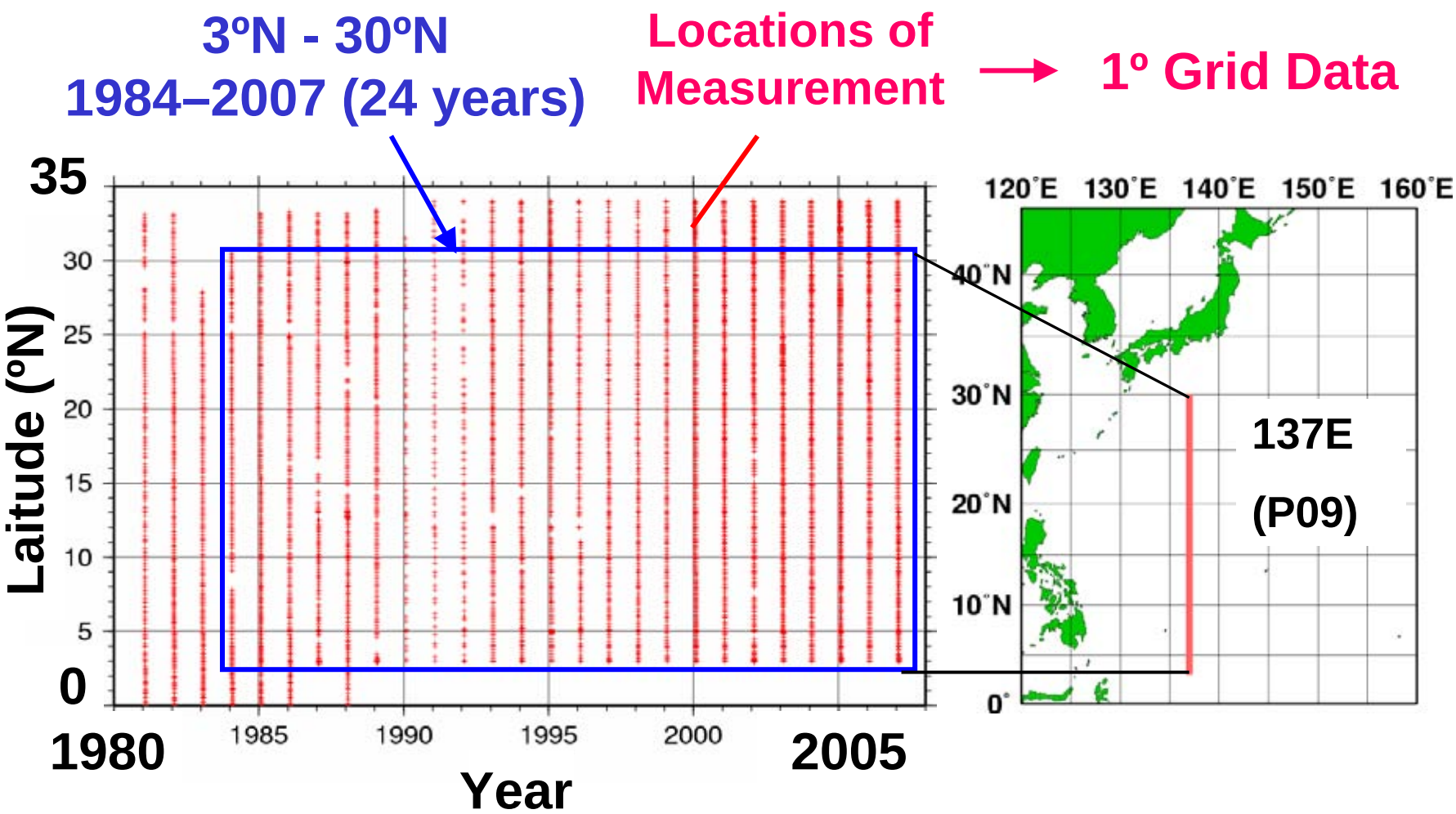
pCO_2 increase

mean of 3º - 30ºN

This study

- To find the dominant spatial structure of the interannual variations in pCO_2
- To consider the controlling factors of the variations

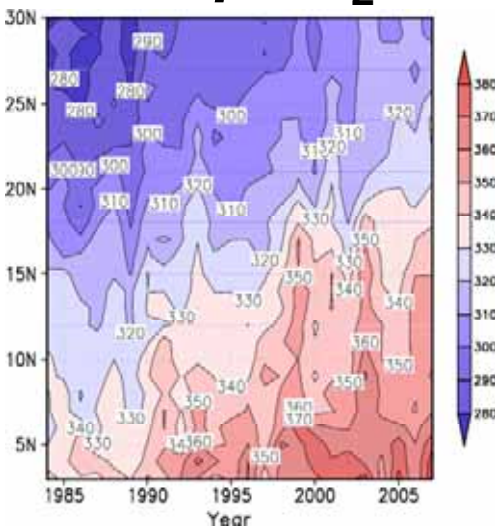
Used Data



All Data are Available from
WDCGG (WMO World Data Centre for Greenhouse Gases)
URL: http://gaw.kishou.go.jp/wdcgg/wdcgg.html

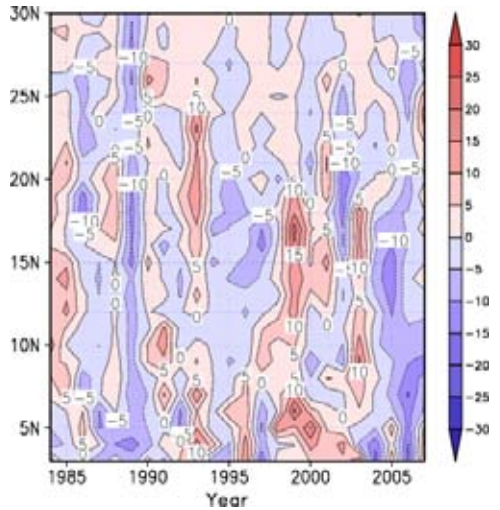
Data Processing

Raw pCO_2^{sea}

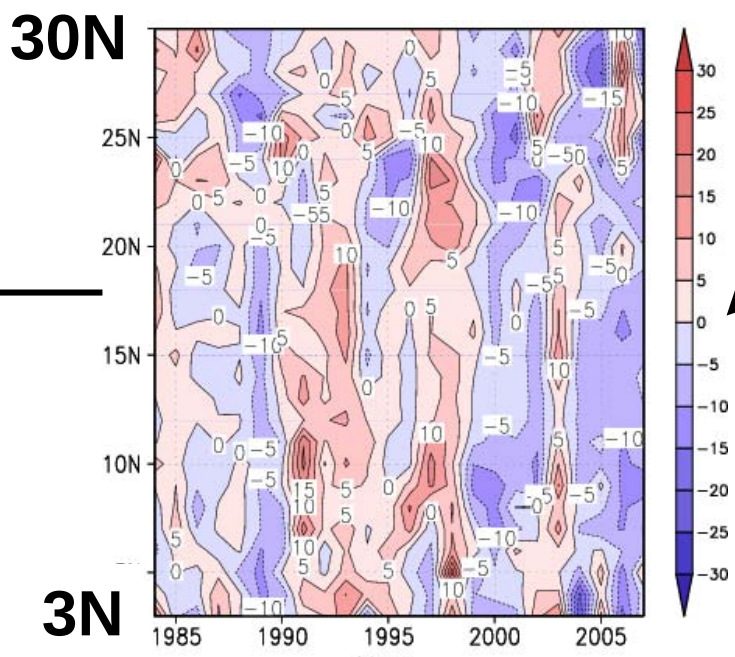


Trend and Offset Removing

Detrended



Normalized [n-pCO_2]

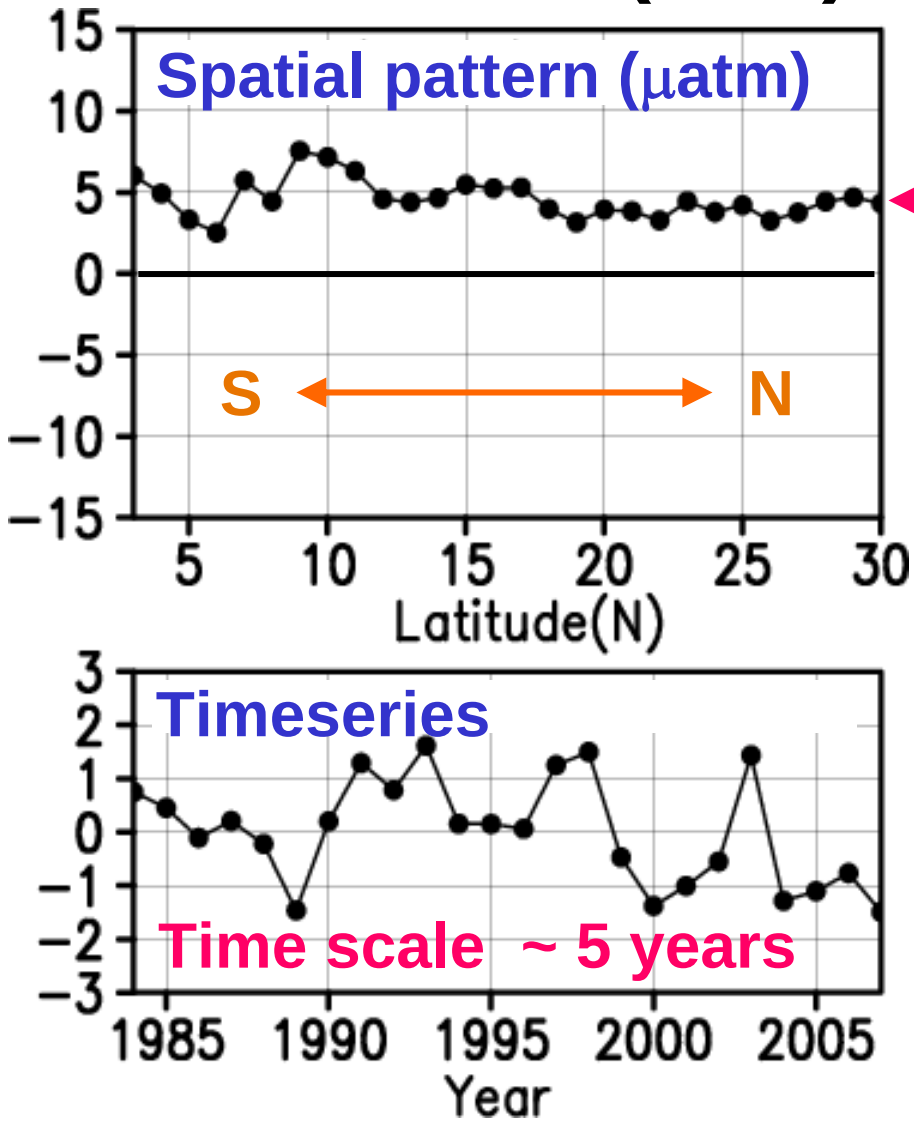


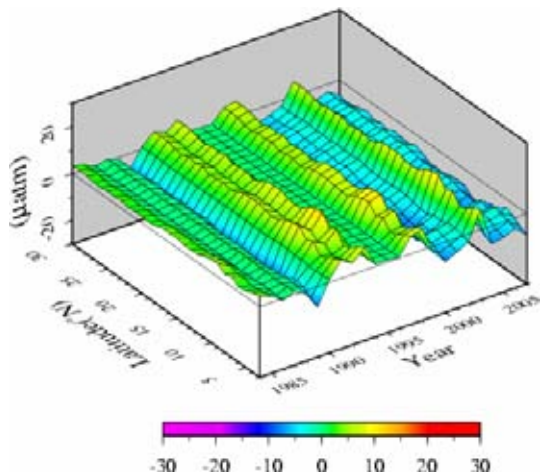
Thermodynamical Variations by STT and SSS Normalizing (Weiss et al., 1982)

Spatial Structure is found

Extraction of Spatial Structure through EOF Analysis (Empirical Orthogonal Function analysis)

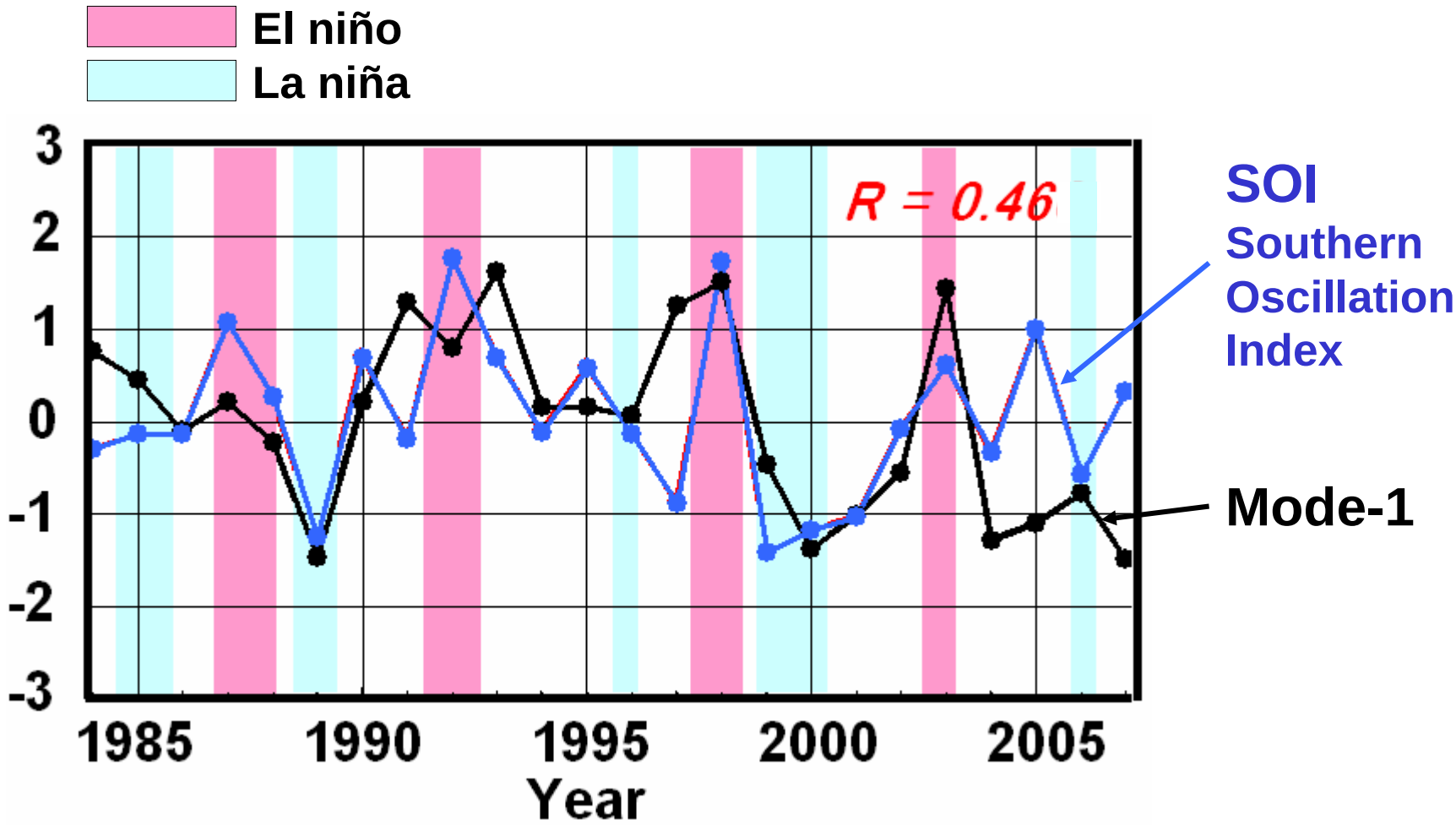
The 1st EOF mode of n(normalized)-pCO_2 (39%)



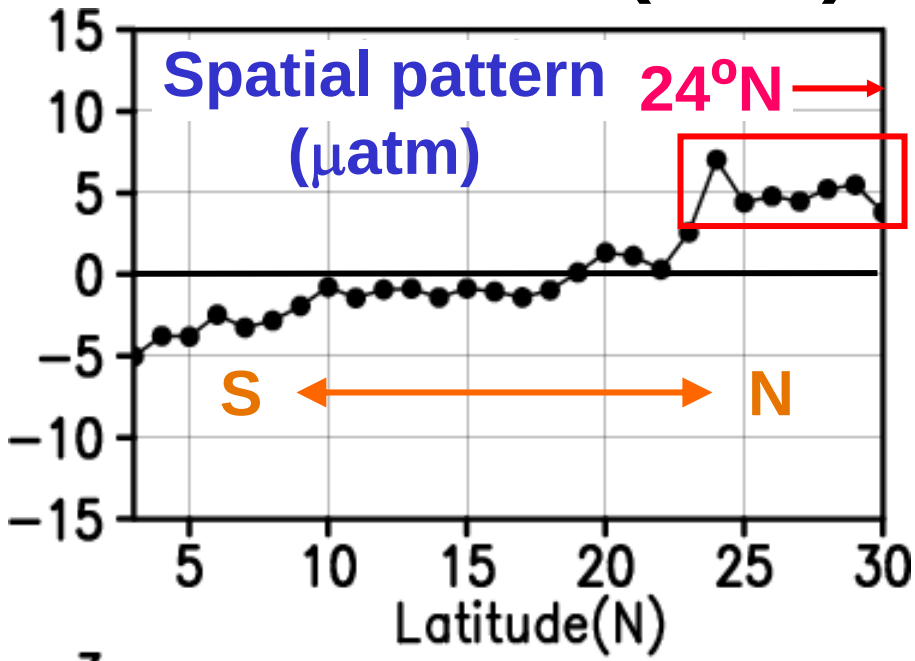


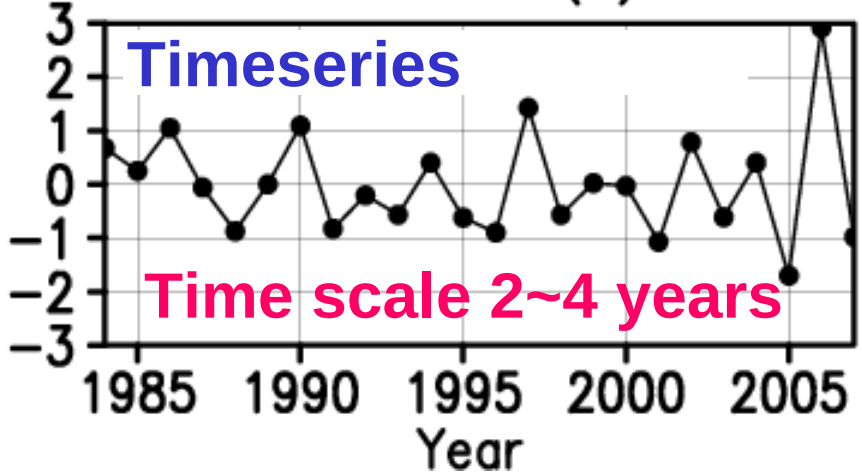
Reconstructed

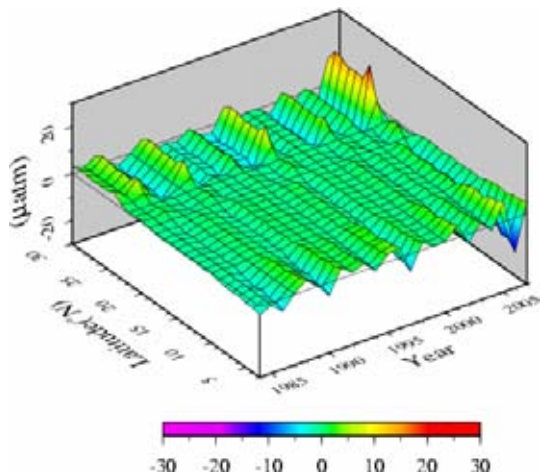
High Correlation with ENSO



The 2nd EOF mode of n(normalized)-pCO_2 (18%)



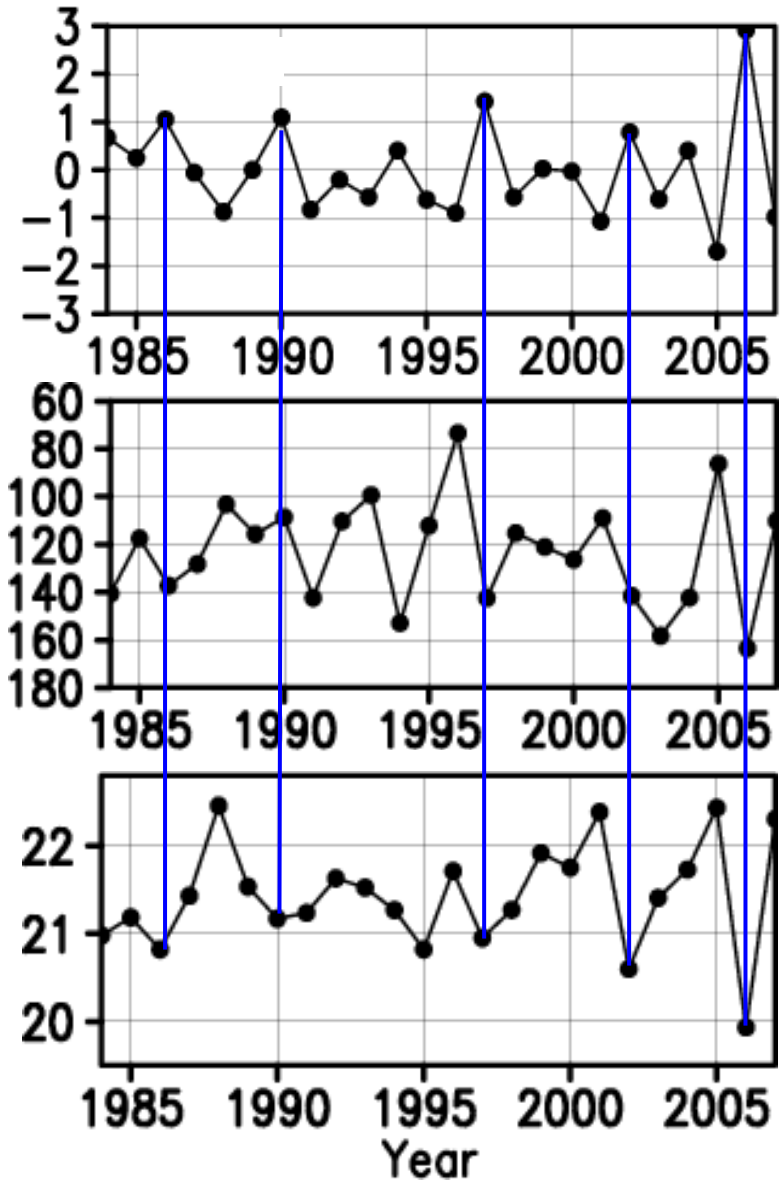




Reconstructed

High Correlation with Mixed Layer Depth

Mode-2



Mixed Layer Depth (m)

↑

Mean north of 24°N

↓

Mixed Layer Temp. (°C)

↓

Entrainment

↓

DIC increase

↓

pCO_2 increase

R = 0.64

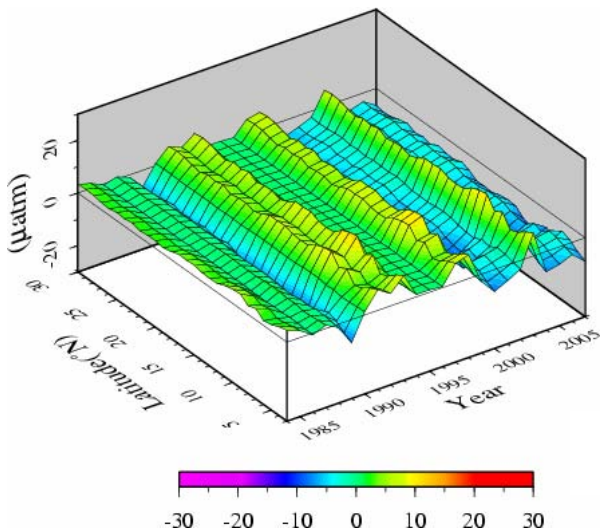
R = -0.78

Discussion on Spatial Structure of Mode-1

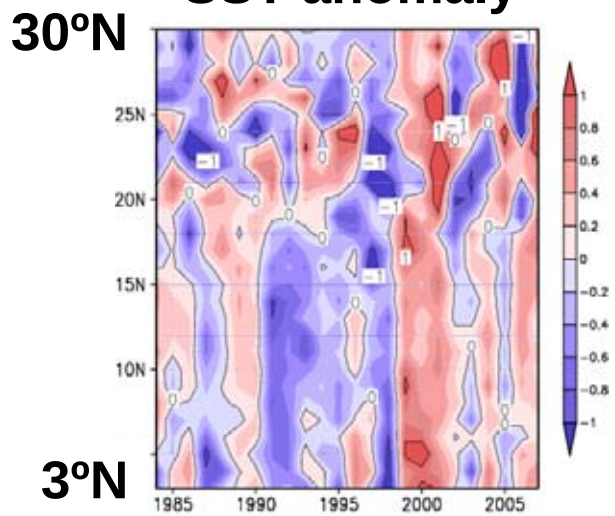
- **Large Variations along entire 137ºE (P09) Line**
  - **Meteorological Parameters**
    - **Wind speeds have low correlation**
  - **Mixed Layer Depth**
    - **High correlation only north of about 25ºN**
  - **SST** **NOTE: Related to the Change in Surface DIC**
    - **High correlation (R = -0.70)**

Now no answer!

n-pCO_2 Mode-1



SST anomaly



Summary

- Seawater pCO_2 without the variations controlled by thermodynamics of SST and SSS remain the interannual variations in the western North Pacific.
- Using 24 years' winter oceanic pCO_2 along 137ºE, detrended and normalized, spatial structure associated with the interannual variations in pCO_2 were extracted through EOF analysis.
- The 1st and 2nd mode account for 39% and 18% of the contributions to the interannual variations in pCO_2, respectively

1st mode 39%	Amplitude: ~ 5 μatm between 3°N and 30°N Time Scale: ~ 5 years High Correlation: ENSO and …
2nd mode 18%	Amplitude : ~ 5 μatm north of 24°N Time Scale: 2~4 years High Correlation: Mixed Layer Depth / Temperature

References

- **Inoue H. Y., H. Matsueda, M. Ishii, K. Fushimi, M. Hirota, I. Asanuma and Y. Takasugi (1995), Long-term trend of the partial pressure of carbon dioxide (*p*CO_2) in surface waters of the western North Pacific, 1984 - 1993., *Tellus*, Ser. B, 39, 228 - 242.**

- **Midorikawa T., M. Ishii, K. Nemoto, H. Kamiya, A. Nakadate, S. Masuda, H. Matsueda, Toshiya Nakano and H. Y. Inoue (2006), Interannual variability of winter oceanic CO_2 and air-sea CO_2 flux in the western North Pacific for 2 decades., *J. Geophys. Res.* 111, C07S02, doi:10.1029/2005JC003095**

- **Weiss R. F., R. A. Jahnke and C. D. Keeling (1982), Seasonal effects of temperature and salinity on the partial pressure of CO_2 in seawater, *Nature*, 300, 511 - 513.**