Interannual variability of winter oceanic CO$_2$ along 137°E in the western North Pacific

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**JMA’s observation of CO₂**

$p\text{CO}_2$
- **Repeat lines**
  - 137°E (P09, 1981~) and 165°E (P13, 1996~)

- **Research vessels**
  - Ryofu Maru and Keifu Maru

- **Frequency**

**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

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

3ºN - 30ºN
1984–2007 (24 years)

Locations of Measurement → 1º Grid 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 $pC\text{O}_2^{\text{sea}}$

Trend and Offset Removing

Normalized $[n-pC\text{O}_2]$

Spatial Structure is found

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

Detrended

Thermodynamical Variations by STT and SSS Normalizing (Weiss et al., 1982)
The 1\textsuperscript{st} EOF mode of n(normalized)-pCO\textsubscript{2} (39%) 

Spatial pattern ($\mu$atm) 

Time scale $\sim$ 5 $\mu$atm 

Reconstructed
High Correlation with ENSO

El niño
La niña

SOI Southern Oscillation Index
Mode-1

$R = 0.46$
The 2\textsuperscript{nd} EOF mode of $n(\text{normalized})$-$pCO_2$ (18\%)

**Spatial pattern**

- $24^\circ$N
- $\mu$atm
- $\sim 5\mu$atm

**Timeseries**

- Time scale 2\textendash{}4 years

**Reconstructed**
High Correlation with Mixed Layer Depth

Mode-2

Mix Layer Depth (m)

Mean north of 24ºN

Mix Layer Temp. (ºC)

Entrainment

DIC increase

$pCO_2$ increase

R = 0.64

R = -0.78
Discussion on Spatial Structure of Mode-1

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

Now no answer!
Summary

• Seawater $p$CO$_2$ without the variations controlled by thermodynamics of SST and SSS remain the interannual variations in the western North Pacific.

• Using 24 years’ winter oceanic $p$CO$_2$ along 137°E, detrended and normalized, spatial structure associated with the interannual variations in $p$CO$_2$ were extracted through EOF analysis.

• The 1$^{\text{st}}$ and 2$^{\text{nd}}$ mode account for 39% and 18% of the contributions to the interannual variations in $p$CO$_2$, respectively.

<table>
<thead>
<tr>
<th>Mode</th>
<th>Amplitude</th>
<th>Time Scale</th>
<th>High Correlation</th>
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</thead>
<tbody>
<tr>
<td>1$^{\text{st}}$ mode</td>
<td>$\sim 5$ (\mu\text{atm}) between 3°N and 30°N</td>
<td>$\sim 5$ years</td>
<td>ENSO and ...</td>
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<tr>
<td>2$^{\text{nd}}$ mode</td>
<td>$\sim 5$ (\mu\text{atm}) north of 24°N</td>
<td>2~4 years</td>
<td>Mixed Layer Depth / Temperature</td>
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References

