The amount of bubble injection on the concentrations of $N_2$ and $Ar$ in the western North Pacific

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Outline

- Using $N_2$ and $Ar$
- Key word: Preformed sea surface state
- Target: Subsurface water mass
- Amount of bubble injection ($B$)
  - Index of preformed wind speed
- Saturation state ($A$)
  - Index of preformed barometric pressure
- Climate change will affect value of $B$ and $A$
- Preformed $O_2$ and CFCs by using $B$ and $A$
Background: Preformed

High Latitudes, Winter

Highlight Dissolved Gases
Highlight Dissolved Gases

Background: Preformed

High Latitudes, Winter

Isopycnal mixing
**Gas flux process: Two ways**

- **Strong Storm**
  - Gas exchange at surface layer (A)
    - Many bubbles generated
    - Carry to deep part with vertical mixing
    - Forcibly dissolved by pressure

- **Bubble injection (B)**
  - Reflect wind velocity

**Equations**

- Satu(T, S, and P) = equilibrium
- Flux = k (Satu(T, S, and P) - C)

**Explanation**

- A is constrained barometric pressure
- B reflects wind velocity
**N\textsubscript{2} and Ar**

Atmosphere

\[ \text{N}_2 : \text{Ar} = 0.7980 : 0.0090 \quad \sim 88.7 \quad \text{Constant} \]

Solubility \[ \text{N}_2 : \text{Ar} = 1:2 \]

Saturation conc. (winter)
\[ \text{N}_2 : \text{Ar} = 605 : 16.5 \quad \sim 36.7 \]

+ Bubble injection
Shift \( \sim 36.7 \) to \( \sim 88.7 \)

Conservative contents in subsurface
(Denitrification is very little in water column)
High precision analytical method (Tanaka and Watanabe, 2007)

Precision < 0.1 %

Thus, concentration of $N_2$ and $Ar$ in subsurface depend on preformed surface state!!
Estimates of $A$ and $B$ by $N_2$ and Ar

$N_2 \text{obs} = A \times N_2 \text{sat} + 0.7809 \times B \quad (1)$

$Ar \text{obs} = E_{Ar} \cdot A \times Ar \text{sat} + 0.0093 \times B \quad (2)$

$N_2 \text{sat}$, $Ar \text{sat}$: Saturation state using by T, S (1 atm., $\mu$mol/kg)

$E_{Ar}$ corrected difference between gas exchange rate of $N_2$ and Ar

Error of $B$: $\pm \sim 4 \; \mu$mol/kg, $A \pm \sim 0.06$
Sampling area

Northern Western North Pacific

A-line
R/V Hokko-Maru
A4,7,11 and 17

1 station 23 layers
10 ~ 3000m

Sampling

Analytical method

Tanaka and Watanabe, 2007
Results, $\theta$, S, $N_2$, and Ar conc.
Results: A and B

A

High Pre. 1.00
Low Pre. 0.94

B (μmol/kg)

High W. V. 40
Low W. V. 0
High wind velocity

Low wind velocity

High Pressure and/or long stay

Low Pressure and/or short stay, ice cover etc...

$B$ vs $A$ on $\text{Sigma}\theta$

$B$ (µmol/kg)

1.00

0

1500~2500m

27.75

25.75

A7_2000,2500m

Low Pressure and/or short stay, ice cover etc…
As each water mass had a significantly different value of $B$ and $A$, it is possible that we can use $B$ and $A$ as an index of the preformed sea surface state and as a water mass indicator.
Saturation state of Preformed Other Gases

\[ SpreZ = \left( E_Z \times A \times Z_{\text{satu}} + Z \text{ Air Conc.} \times B \right) / Z_{\text{satu}} \]

\[ \text{SpreO}_2 \]
\[ 96\sim100\% \]
\[ \text{AOU} \]
\[ \sim14 \text{ \(\mu\)mol/kg} \]
\[ \text{Over estimated} \]

It is necessary to re-estimate the oceanic uptake of anthropogenic CO\(_2\) by using \text{PreO}_2
Saturation state of Preformed Other Gases

\[
SpreZ = (E_Z \times A \times Z_{\text{satu}} + Z \text{ Air Conc.} \times B) / Z_{\text{satu}}
\]

It is necessary to re-estimate the pCFCs age by using PreCFCs.
Conclusion

• Each water mass has characteristic $A$ and $B$.
• It is possible that we can use $B$ and $A$ as an index of the preformed sea surface state and as a water mass indicator.
• Preformed other gases can be estimated by $A$ and $B$. It is necessary to re-estimate the various estimates.

Future Plan

• Time series observation
  (Climate change, e.g., NPIW)
• Spatial distribution of $N_2$ and Ar
• Correlation between surface condition ($P$, $T$, Wind speed) and $A$, $B$ by time series observation during winter on the sea surface.
Thank you!!