An increasing of silicic acid and nitrate concentrations along the pathway of Lower Circumpolar Deep Water in the Pacific Ocean: Results of snap shots comparisons

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International Symposium: Effects of Climate Change on the World's Oceans
May 2008, Gijon, Spain
Talk outline

1, Objectives

2, Results and discussion
1) Observed Silicic acid (hereafter Silicate), Nitrate and dissolved oxygen (hereafter DO) concentrations changes in deep water in the Pacific Ocean

2) Relationship between the pioneering findings of abyssal warming and silicate/DO change: Weakening of overturn?

3, Conclusions
Deep ocean measurements: reasons why?

The ocean works on Climate Change in two ways:

• Thermal inertia: the oceans have soaked up ~50% of the excess heat trapped by the planet due to the Greenhouse effect over the last 50 years

• It is a major carbon sink: about ~30% of the anthropogenic carbon emitted into the atmosphere

Themes of this international symposium:

*Theme 1. Past and future variability and change in ocean climate*

*Theme 2. Interactions between climate variability and change and biogeochemical cycles*

*Theme 3. Impacts of climate variability and change on the coastal environment*

*Theme 4. Impacts of climate change on marine ecosystems: Present status of our understanding*

*Theme 5. Scenarios-mitigation-reduction of impact of future climate change on the marine environment: From regional to global scale*
Full depth comprehensive hydrography: outcomes

• Detecting ocean climate change
• Constraining ocean inventories of heat, carbon, biogeochemical parameters and freshwater -> improved global budgets
• Improving our understanding of ocean/climate physics/biogeochemistry, and thus improve our models
• Compare and test model predictions
7 hydrographic sections used in this study:
Temperature, DO, silicate and nitrate

<table>
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Bold: Cruises by R/V Mirai, JAMSTEC. During these cruises, we used reference materials of nutrients in seawater to keep comparability among the all stations of the cruises.
WOCE and pre-WOCE cruises in 1990s and 1980s

Locations of hydrographic sections (black dots)

CLIVAR/WOCE revisited cruises in 2000s
7 hydrographic sections used in this study:
Temperature, DO, silicate and nitrate

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Pioneering findings of abyssal warming (0.01 ~ 0.003°C) in recent years in the Pacific Ocean

Fukasawa et al., *Nature*, 2004
Kawano et al., *GRL*, 2006
Also along P16 by Johnson et al., *J. Climate*, 2007

The signal is strong in the South Pacific
Less comparability of historical nutrients data because there is no international agreed reference materials of nutrients in seawater

- IPCC 2007 WG1 Chapter 5 Observations: Oceanic Climate Change and Sea Level

5.4.4 Nutrients

Changes in nutrient concentrations can provide information on changes in the physical and biological processes that impact the carbon cycle and could potentially be used as indicators for large scale changes in marine biology. However, only a few studies reported decadal changes in inorganic nutrient concentrations.

In the North Pacific, the concentration of N (nitrate + nitrite) and P (phosphate) decreased at the surface (Freeland et al., 1997; Watanabe et al., 2005) and increased at the sub-surface (Emerson et al., 2001; Ono et al., 2001; Keller et al., 2002) in the past two decades. Nutrient changes were observed in the deep ocean of all basins but no clear pattern emerges from available observations. Pahlow and Riebesell (2000) found changes in the ratio of nutrients in the North Pacific and Atlantic oceans, and no significant changes in the South Pacific. In the North Pacific, Keller et al. (2002) observed a decrease in N associated with the increase in O2 between 1970 and 1990 at 1050 m, opposite to Pahlow and Riebesell’s longer study. Using the same data set extended to the world, large regional changes in nutrient ratios were observed (Li and Peng, 2002).

But no consistent basin-scale patterns. Uncertainties in deep ocean nutrient observations may be responsible for the lack of coherence in the nutrient changes. Sources of inaccuracy include the limited number of observations, and the lack of compatibility between measurements from different laboratories at different times.
Global observation using Global Reference Material has been establishing comparability of nutrients data among the CLIVAR cruises.

With global RMNS in 2003-2007 on R/V Mirai

Global Reference Material and International Nutrients Scale System: see MRI web site
DO difference vs. silicate difference (a) and nitrate difference vs. silicate difference (b) along P14N line between 2007 and 1993, theta 1.0 – 1.2 deg.

(a) Before offset correction

- Silicate difference / micro mol kg⁻¹
- Dossolved oxygen difference / micro mol kg⁻¹

- y = -5.9 - 0.7x   R= 0.70

(b) After tentative offset correction

- Silicate difference / micro mol kg⁻¹
- Nitrate difference / micro mol kg⁻¹

- Raw data
- After tentative offset correction
DO difference vs. silicate difference (a) and nitrate difference vs. silicate difference (b) along P14N line between 2007 and 1993

Negative relationship between DO and silicate, positive relationship between nitrate and silicate are found. However, less comparability among the chemical analysis in different cruises is found as already reported. (Aoyama et al., 1996; Gouretski, 1999; Johnson et al., 2001; IPCC2007)

We need global certified reference materials of the nutrients measurements and International Nutrients Scale System, INSS, to solve this problem.
Rates of silicate concentration change in the deep water (theta = 1.0 to 1.2) during 2000s and 1990s/1980s: Raw

Less comparability among silicate concentrations
Rates of dissolved oxygen concentration change in the deep water (theta = 1.0 to 1.2) during 2000s and 1990s/1980s: raw

Comparability looks better for DO measurements
Silicate vs. DO

Positive Negative
From now, nutrients and DO data appeared in the figures were corrected by offsets.
Section of \( \Delta \theta \) field for P14N (normally along 178E) between Bering sea to Fiji in 2007 and 1993
Section of δsilicate field for P14N (normally along 179E) between Bering sea to Fiji in 2007 and 1993.
Section of silicate field for P14N (normally along 178E) between Bering Sea to Fiji. In 2007 and 1993 overlayed on 3D bottom topography (150E-180E, 20S – 60N).
Silicate, Nitrate and dissolved oxygen differences in terms of micro mol kg\(^{-1}\) along P14N line in 2007 and 1993.
Silicate difference and concentrations along P14 in 2007 and 1993

Silicate increase at warming area

Silicate decrease at cooling area

Gradient decrease observed. This suggest that low silicate/ high DO CDW comes less.
Fig. 9 Differences of silicate concentration along P3 line (Fig. 6-2) over 3-D topography at the region 24°N-EQ, 120°E-10°W. (View from north)
Pioneering findings of abyssal warming (0.01 ~ 0.003°C) in recent years in the Pacific Ocean


P01 (47N: 1999 - 1985)  ~ Kawano et al., GRL, 2006

Also along P16 by Johnson et al., J. Climate, 2007

P03 (24N: 2005/6 - 1985)


Warming in the wide area of the Pacific Ocean. The signal is strong in the South Pacific
Tentative correction applied.
These offsets are larger than those for a few cruises in Johnson et al., 2001.
Conclusions:
• Negative relationship between Δsilicate and ΔDO and positive relationship between Δsilicate and Δnitrate in CDW, theta=1.0 – 1.2 deg., were observed.
• There might exist offsets of chemical measurements of silicate, nitrate and DO, though, we can say that gradient of silicate concentration from south to north had deceased in wide areas in the Pacific Ocean.
• The increase of silicate concentration, if we accept offset corrections, clearly coincide with abyssal warming in the western Pacific Ocean, thus, these signals suggest that low silicate/ high DO CDW comes less. In the eastern Pacific Ocean, however, decrease of silicate concentration was observed at abyssal warming regions.
• These changes might suggest weakening of the Pacific overturning circulation.

To improve comparability of nutrients data in the world Ocean:
• We need global reference materials for nutrients measurements and International Nutrients Scale System to ensure global comparability of nutrients data in the world ocean. NO MORE OFFSET!
Estimated offsets of silicate and dissolved oxygen concentrations

<table>
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