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

Michio Aoyama[1], M. Fukasawa[2], T. Kawano[2]
S. Kouketsu[2], Y. Kumamoto[2], A. Murata[2],
K. Sato[3], H. Uchida[2]

1 Meteorological Research Institute,Japan

2 Institute of Observational Research for Global Change, Japan Agency for Marine-Earth Science and Technology, Japan

3 Department of Marine Science, Marine Works Japan Ltd., JAPAN

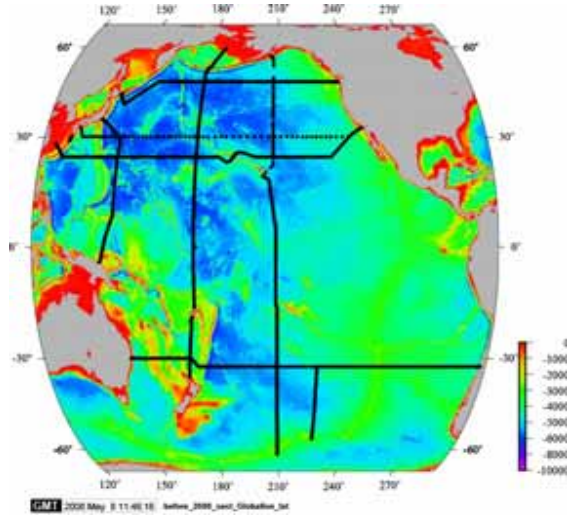
International Symposium: Effects of Climate Change on the World's Oceans
May 2008, Gijon, Spain

Talk outline

1, Objectives

2, Results and discussion

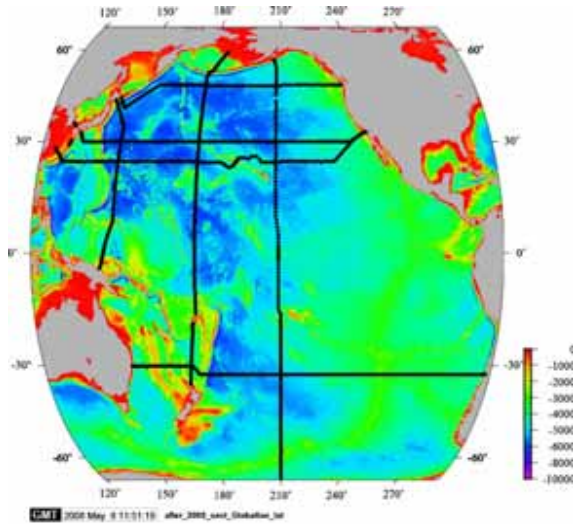
1) Observed Silicic acid (hereafter Silicate) , Nitrate and dissolved oxygen (hereafter DO) concentrations changes in deep water in the Pacific Ocean



WOCE, pre-WOCE

CLIVAR

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

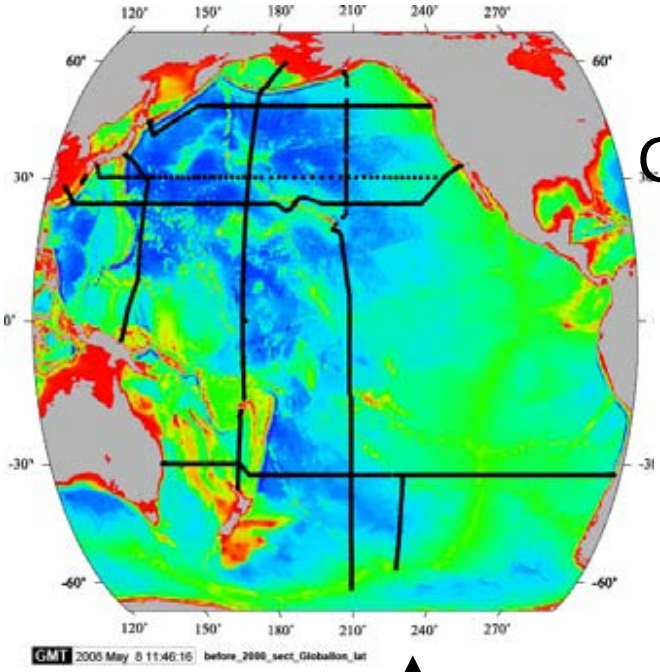
7 hydrographic sections used in this study: Temperature, DO, silicate and nitrate

Section_ID	Nominal lat/lon	CLIVAR	WOCE
P01	47N	**2007**	1999
P02	30N	2004	1994
P03	24N	**2005**	1985
P06	32S	**2003**	1992
P10	149E	**2005**	1993
P14	179E	**2007**	1992
P16	151W	2005	1991

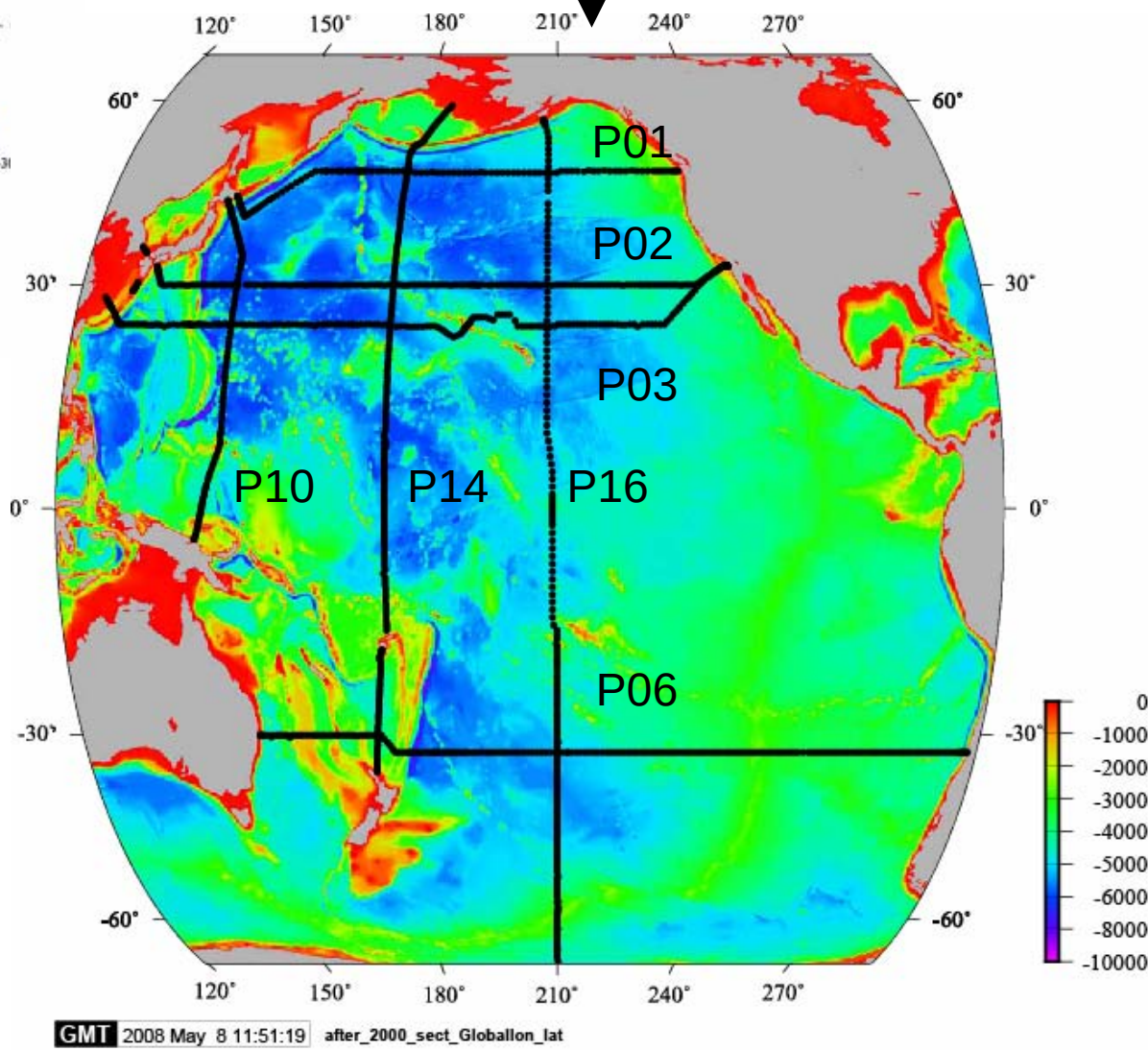
Bold: Cruises by R/V Mirai, JAMSTEC. During these cruises, we used reference materials of nutrients in seawater to keep comparability among the all stations of the cruises.

Locations of hydrographic sections (black dots)

CLIVAR/WOCE revisited cruises in 2000s



WOCE and pre-WOCE cruises in 1990s and 1980s



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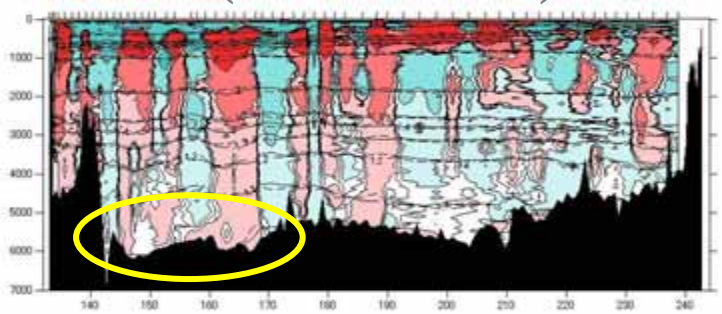
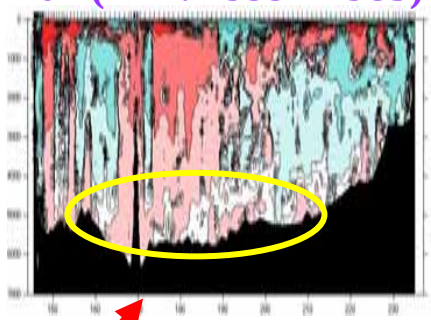
Pioneering findings of abyssal warming （0.01～0.003˚C）

in recent years in the Pacific Ocean

P02 (30N: 2004 - 1994)



P01 (47N: 1999 - 1985)



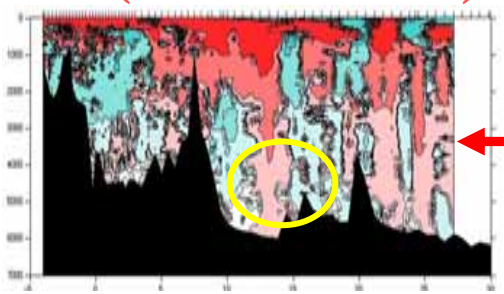
Fukasawa et al., *Nature*, 2004

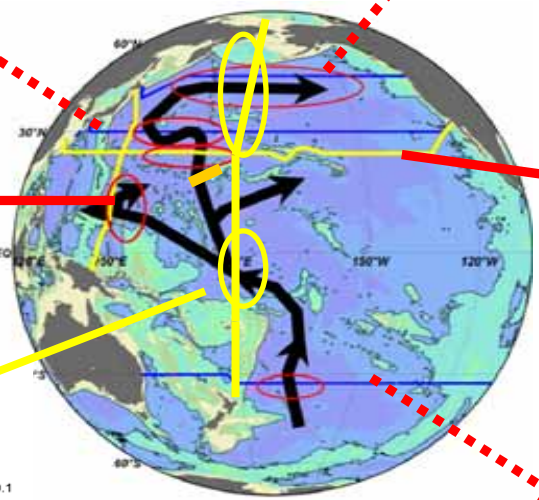
Kawano et al., *GRL*, 2006

Also along P16 by Johnson et al.,

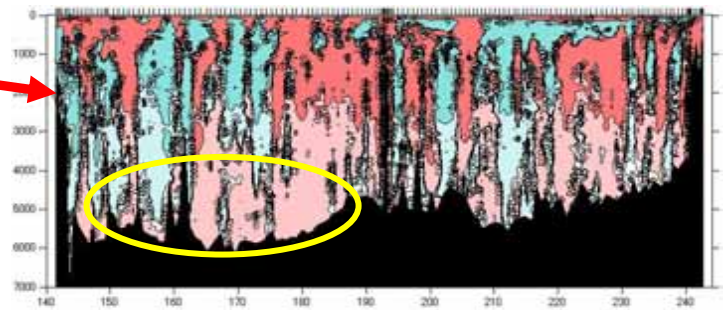
J. Climate, 2007

P10 (149E: 2005 – 1993)

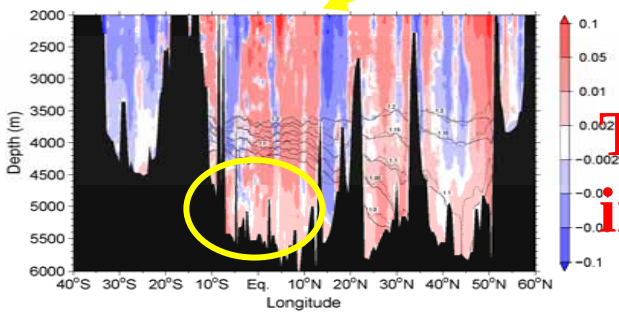




P03（24N: 2005/6 - 1985)

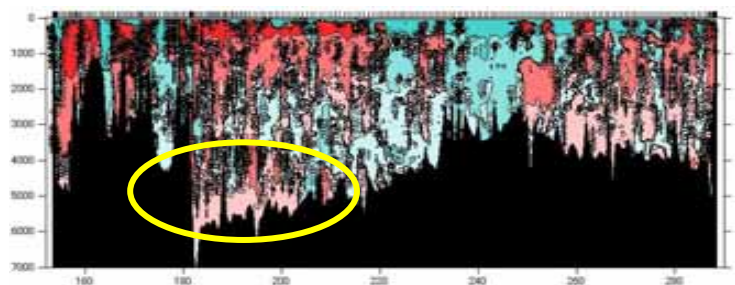


P14(2008-1993）



The signal is strong in the South Pacific

P06 (32S: 2003 - 1992)



Less comparability of historical nutrients data because there is no international agreed reference materials of nutrients in seawater

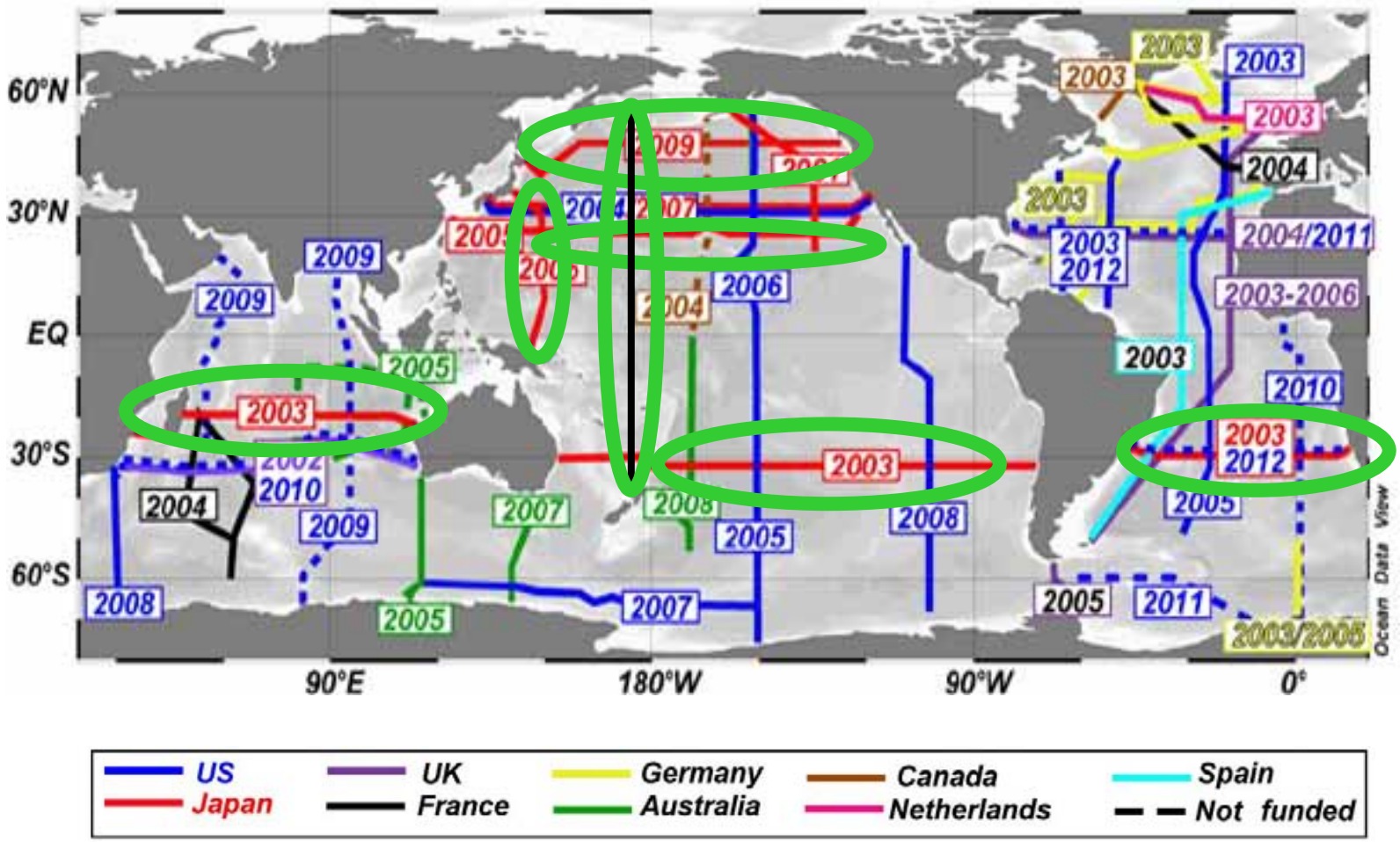
- IPCC 2007 WG1 Chapter 5 Observations: Oceanic Climate Change and Sea Level

5.4.4 Nutrients

- 40
- Changes in nutrient concentrations can provide information on changes in the physical and biological 41
- processes that impact the carbon cycle and could potentially be used as indicators for large scale changes in 42
- marine biology.However, only a few studies reported decadal changes in inorganic nutrient concentrations. 43
- In the North Pacific, the concentration of N (nitrate + nitrite) and P (phosphate) decreased at the surface 44
- (Freeland et al., 1997; Watanabe et al., 2005) and increased at the sub-surface (Emerson et al., 2001; Ono et 45
- al., 2001; Keller et al., 2002) in the past two decades. Nutrient changes were observed in the deep ocean of 46
- all basins but no clear pattern emerges from available observations. Pahlow and Riebesell (2000) found 47
- changes in the ratio of nutrients in the North Pacific and Atlantic oceans, and no significant changes in the 48
- South Pacific. In the North Pacific, Keller et al. (2002) observed a decrease in N associated with the increase 49
- in O2 between 1970 and 1990 at 1050 m, opposite to Pahlow and Riebesell's longer study. Using the same 50
- data set extended to the world, large regional changes in nutrient ratios were observed (Li and Peng, 2002) 51

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.

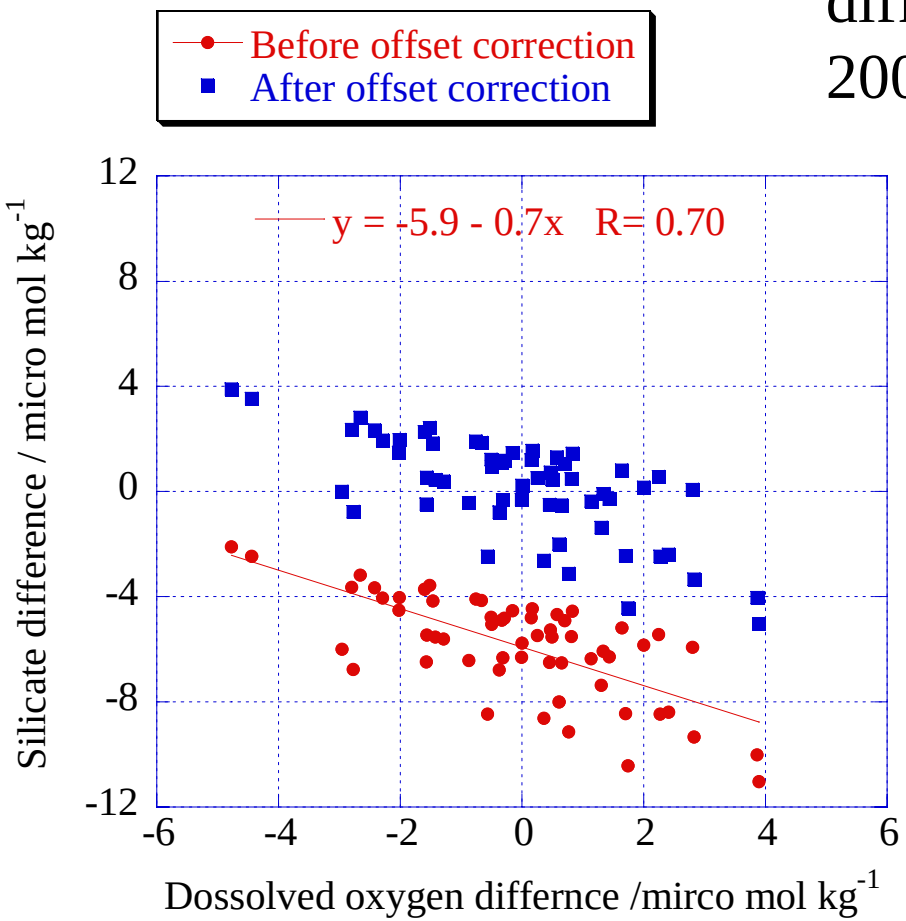


With global RMNS in 2003-2007 on R/V Mirai

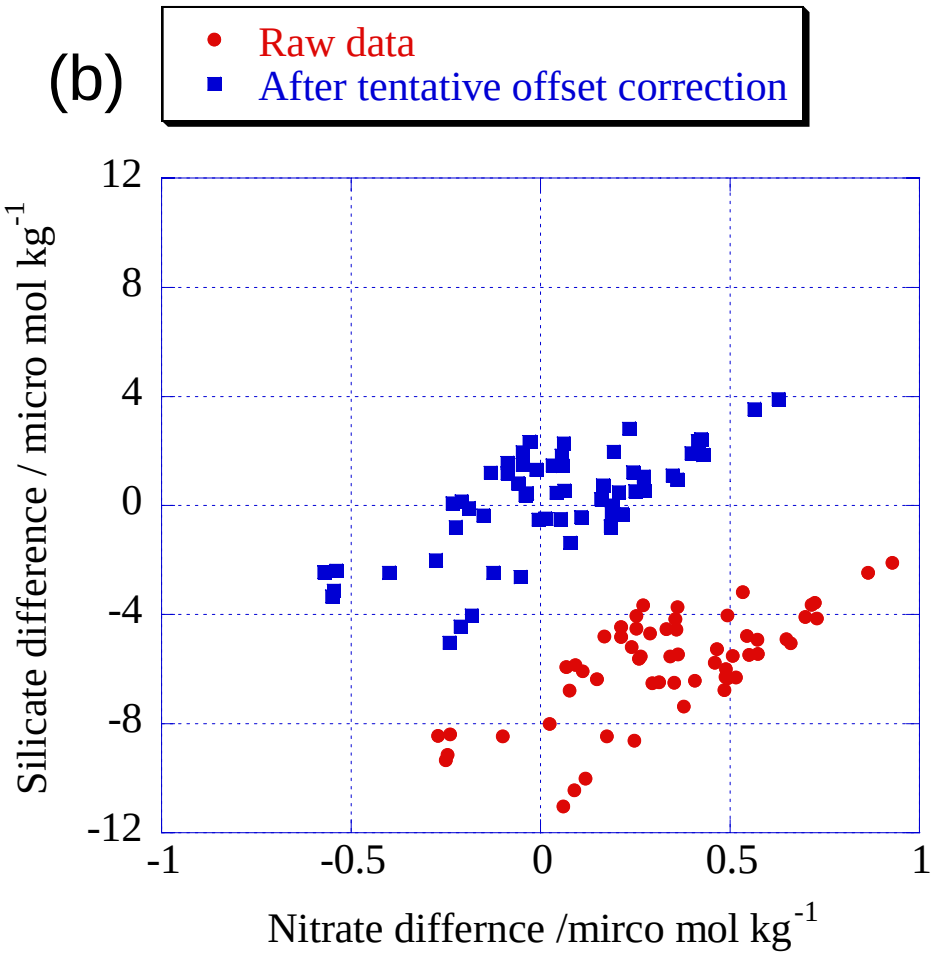
Global Reference Material and International Nutrients Scale System: see MRI web site

(a)

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.



(b)

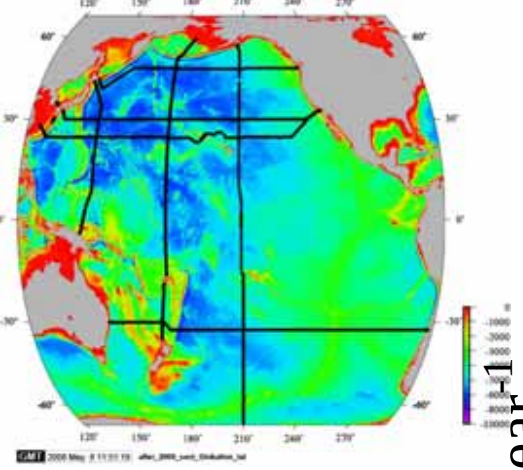


(a)

DO difference vs. silicate difference (a) and nitrate difference vs. silicate difference (b) along P14N line between 2007 and 1993

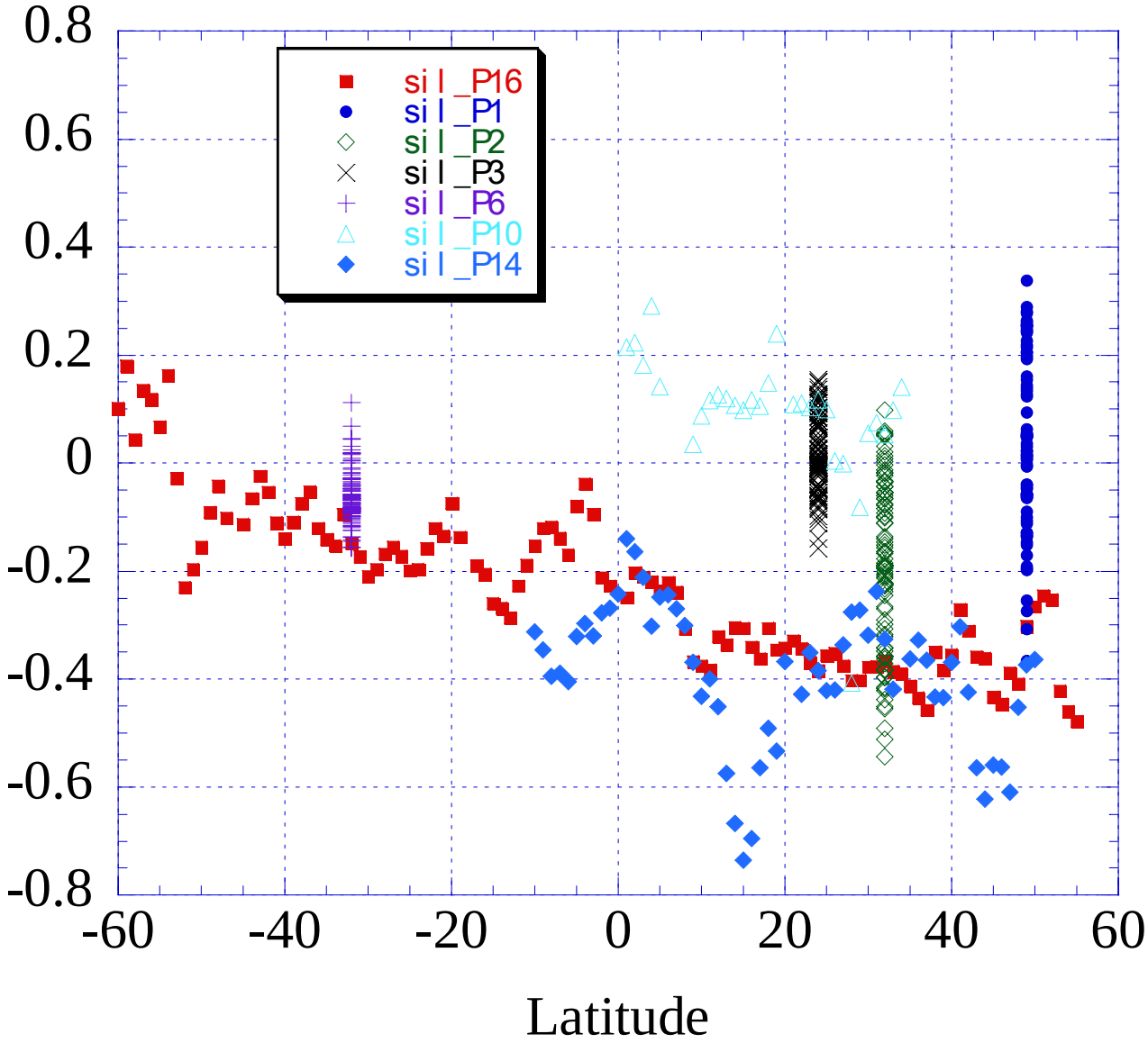
Negative relationship between DO and silicate, positive relationship between nitrate and silicate are found. However, less comparability among the chemical analysis in different cruises is found as already reported. (Aoyama et al., 1996; Gouretski, 1999; Johnson et al., 2001; IPCC2007)

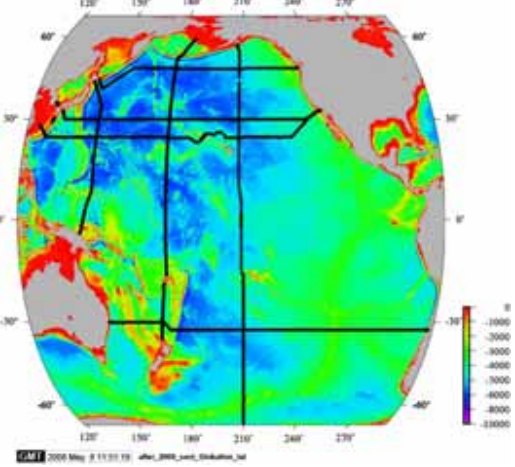
We need global certified reference materials of the nutrients measurements and International Nutrients Scale System, INSS, to solve this problem.



Rates of silicate concnetration chamge in the deep water (theta = 1.0 to 1.2) during 2000s and 1990s/1980s: Raw

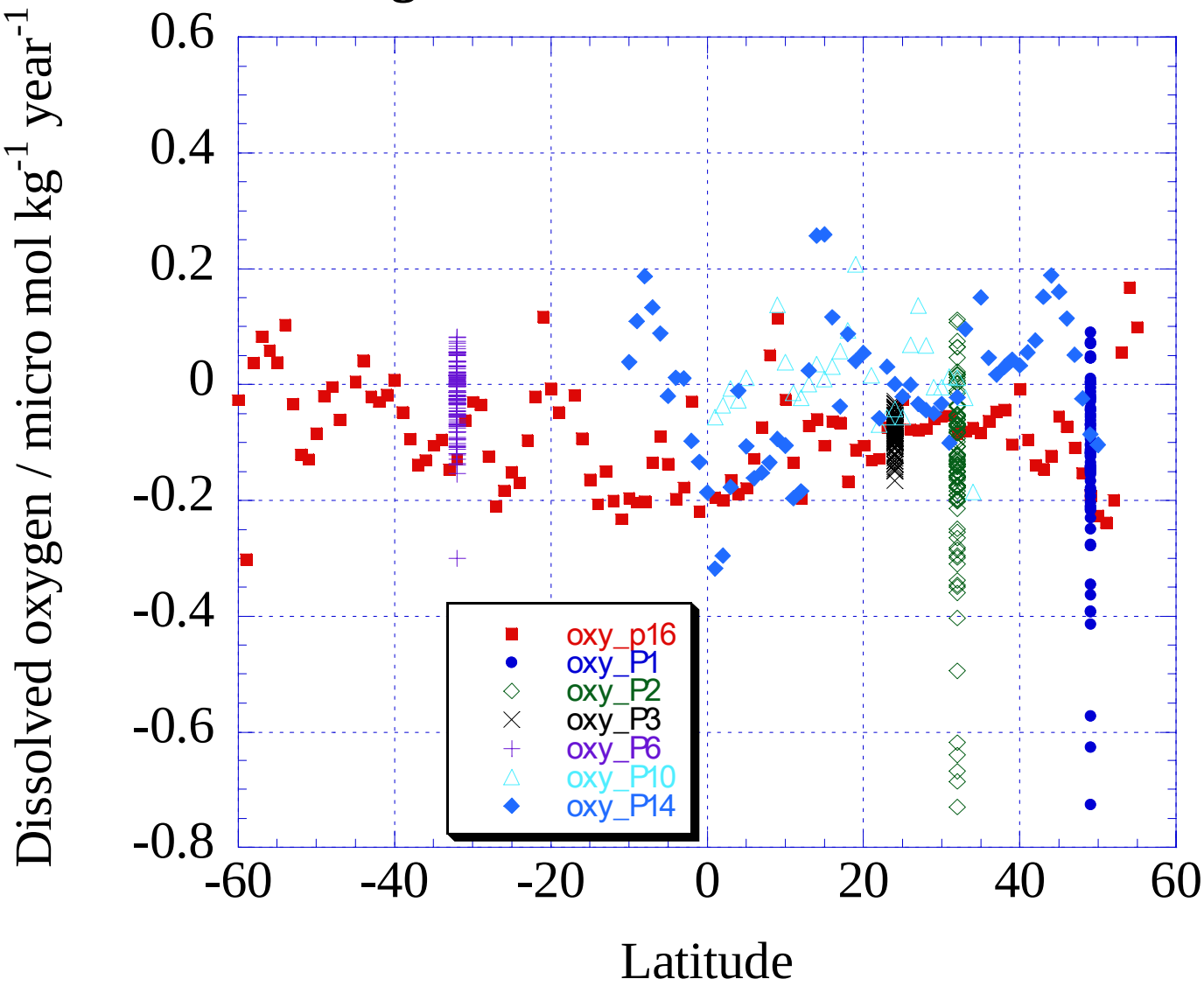
Less comparability among silicate concentrations

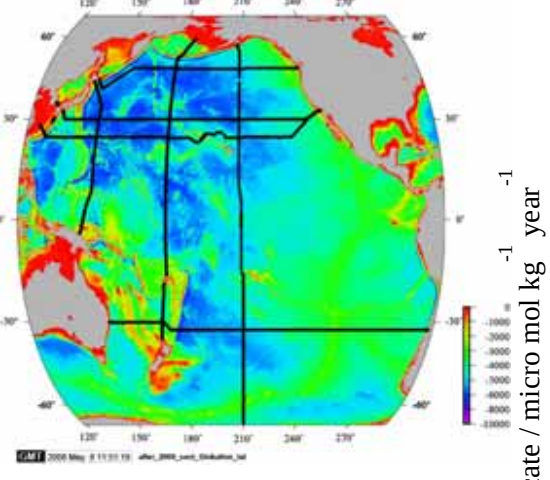




Comparability looks better for DO measurments

Rates of dissolved oxygen concnetration change in the deep water (theta = 1.0 to 1.2) during 2000s and 1990s/1980s: raw

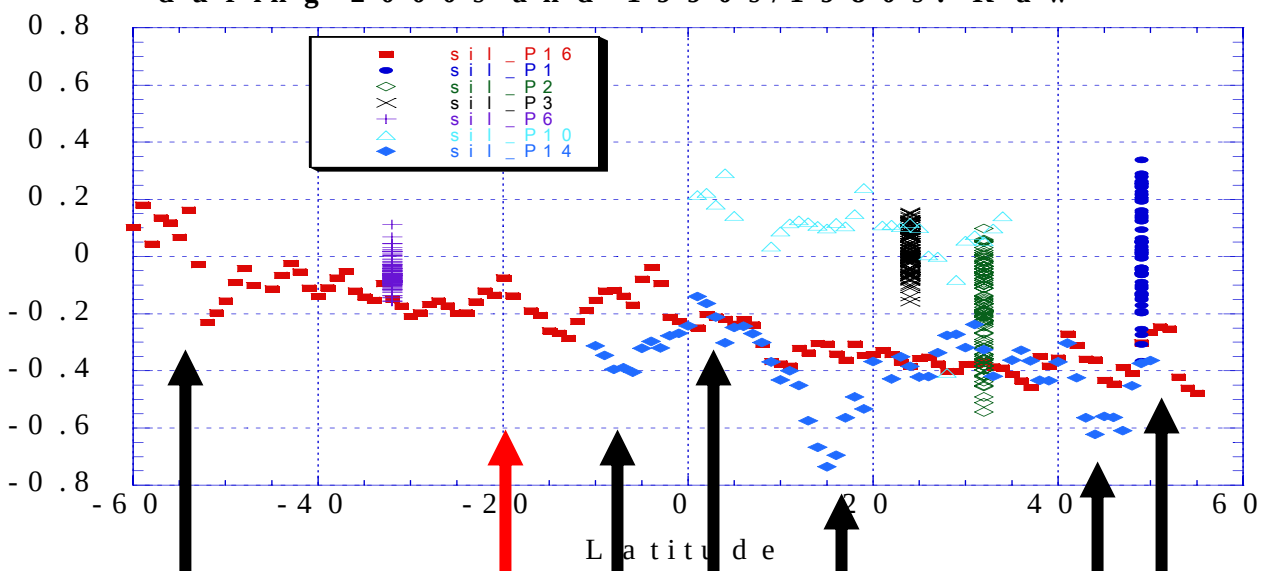




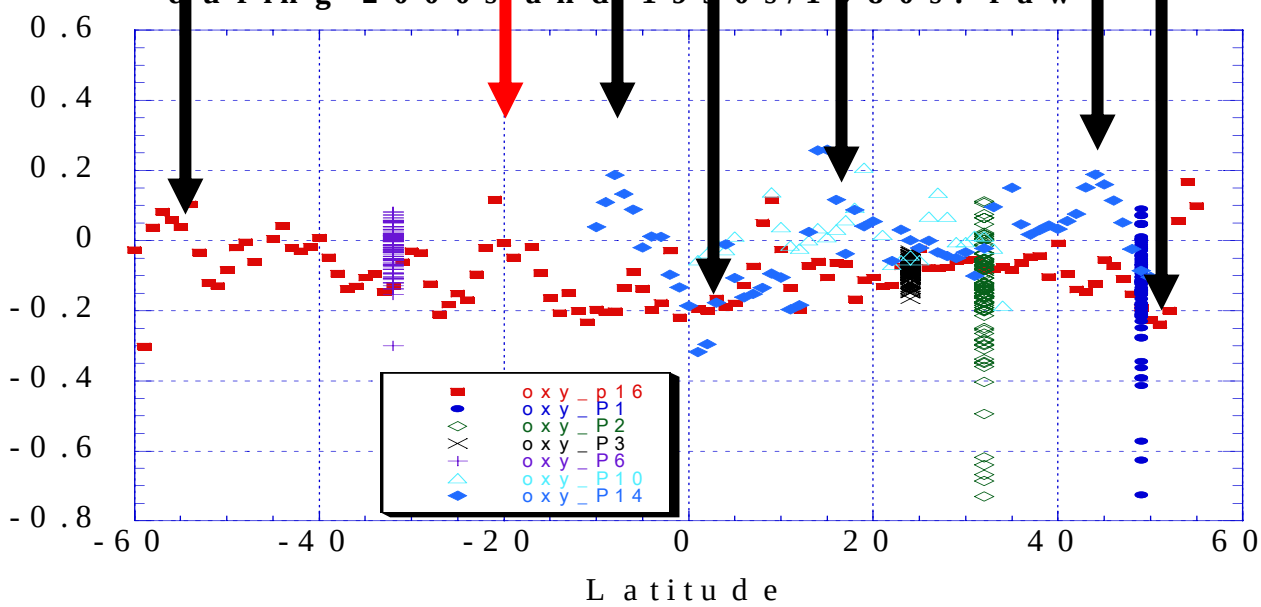
Silicate / micro mol kg $^{-1}$ year $^{-1}$

Silicate vs. DO

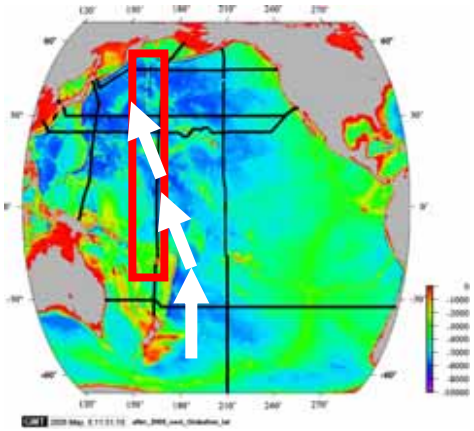
Positive Negative



Dissolved oxygen / micro mol kg $^{-1}$ year $^{-1}$

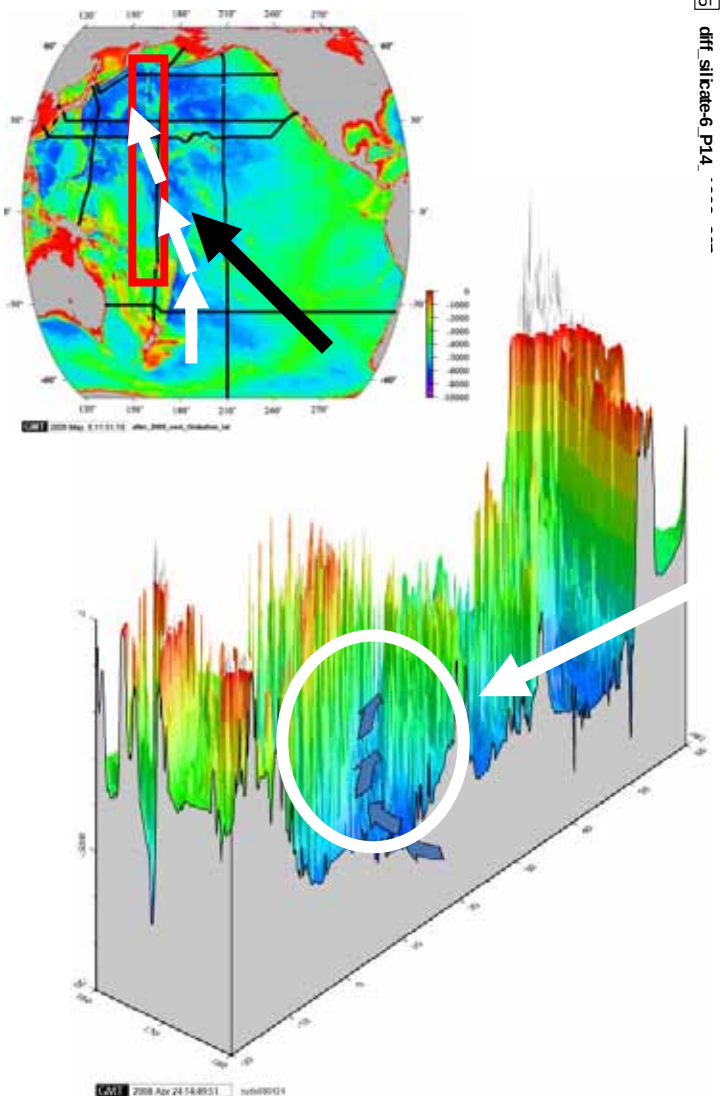


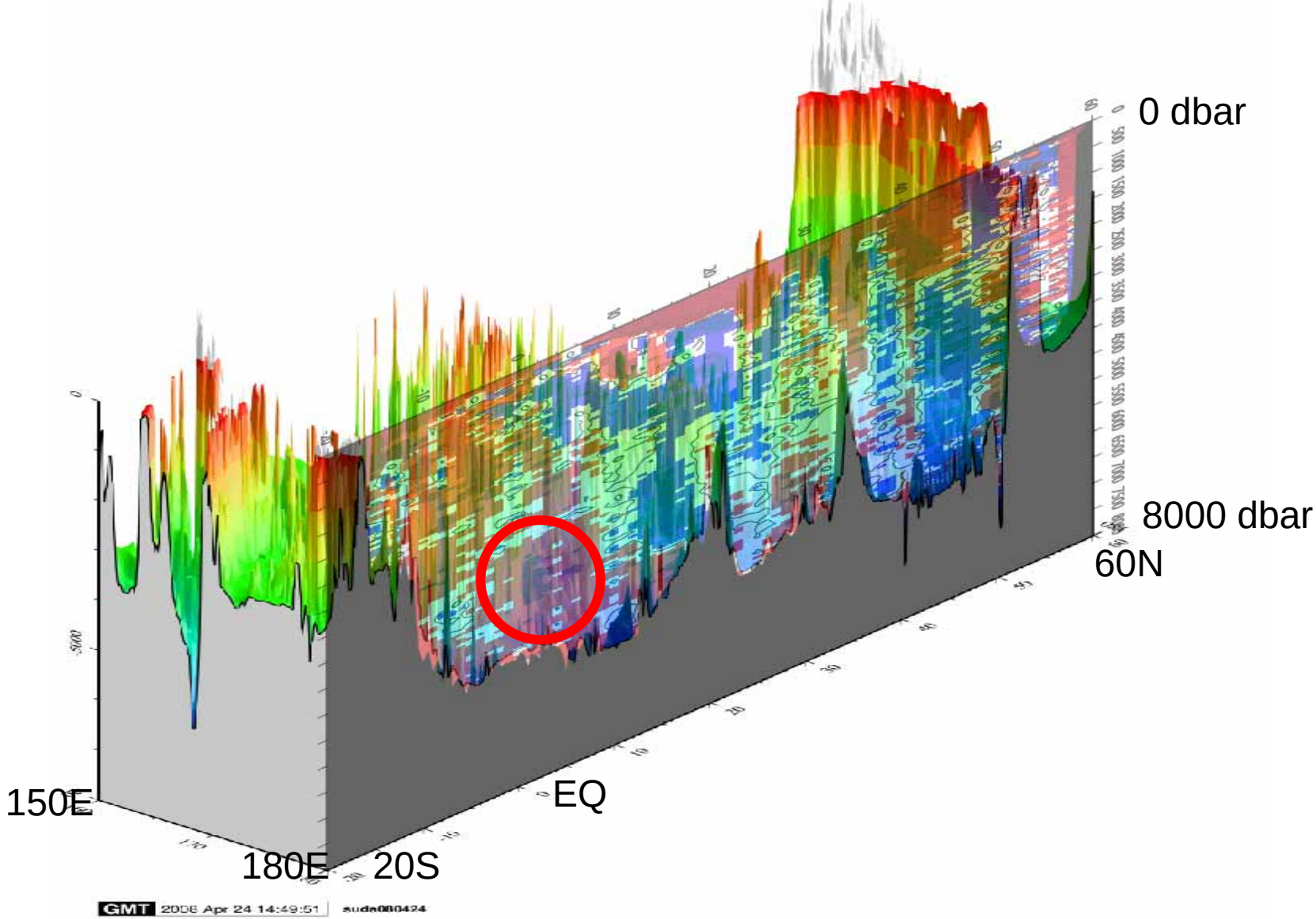
From now, nutrients and DO data appeared in the figures were corrected by offsets



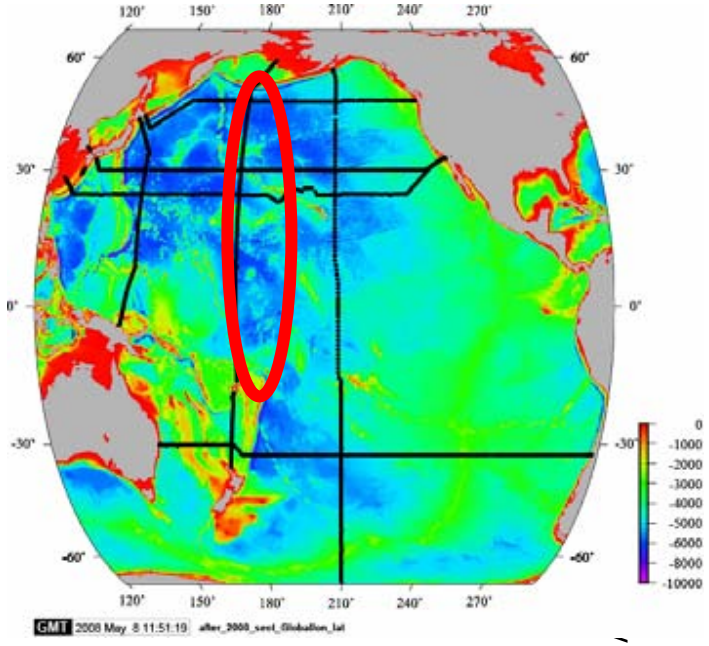
Section of ⊿theta field
for P14N (normally along 178E)
between Bering sea to Fiji
in 2007 and 1993

Section of ⊿silicate field for P14N (normally along 179E)
between Bering sea to Fiji
In 2007 and 1993

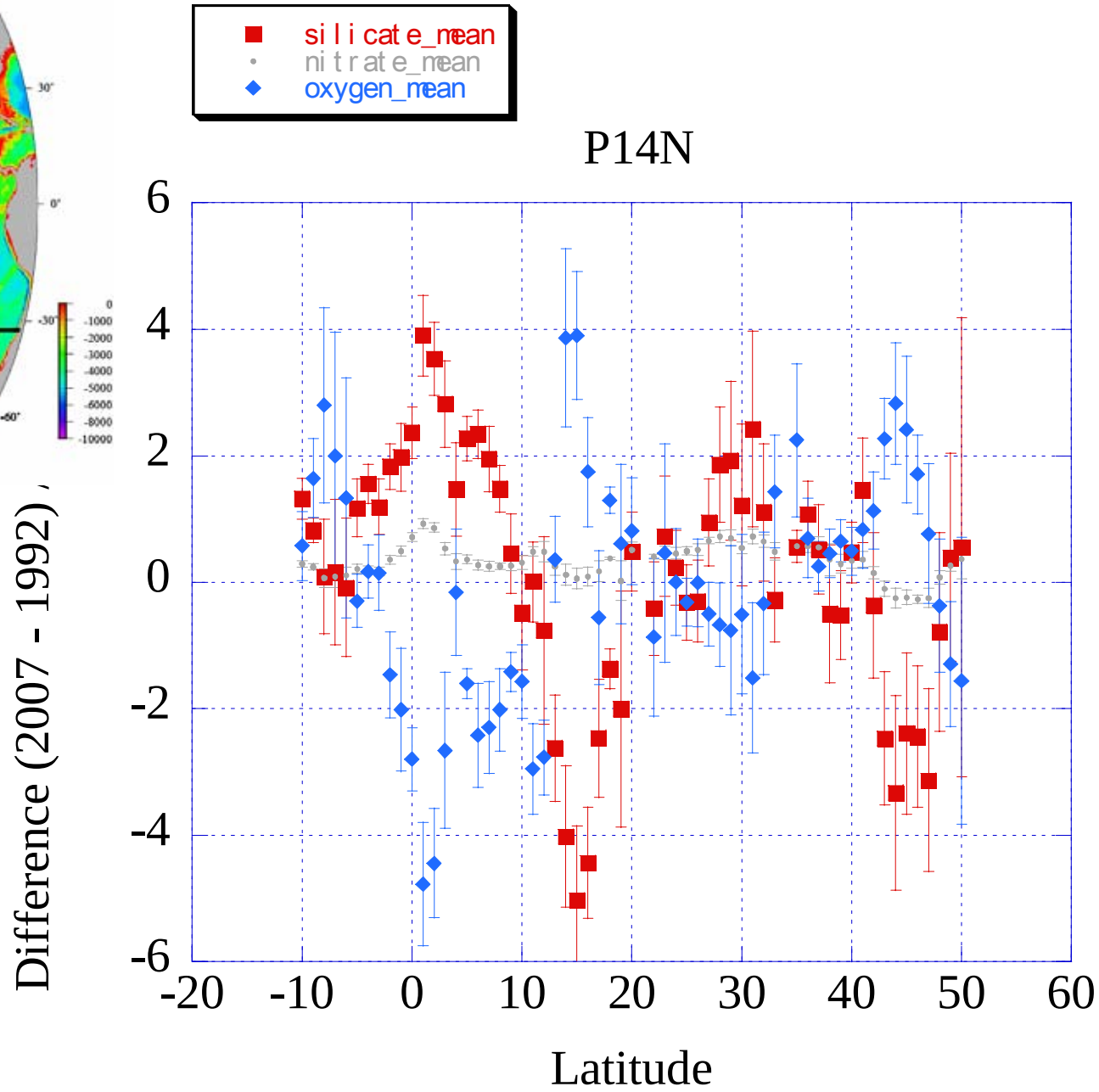




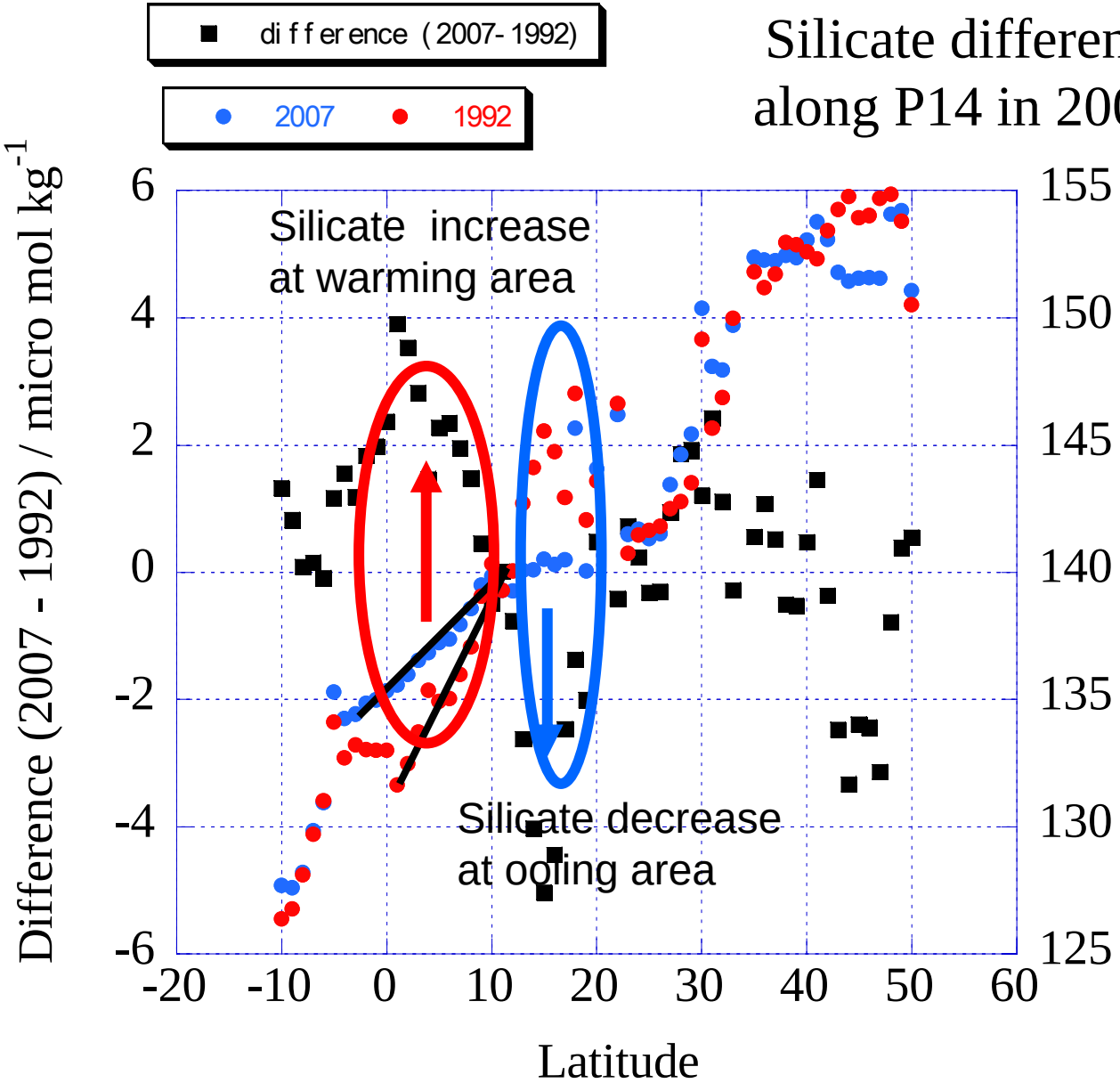
Section of ⊿silicate field for P14N (normally along 178E) between Bering sea to Fiji In 2007 and 1993 overlayed on 3D bottom topography (150E – 180E, 20S – 60N

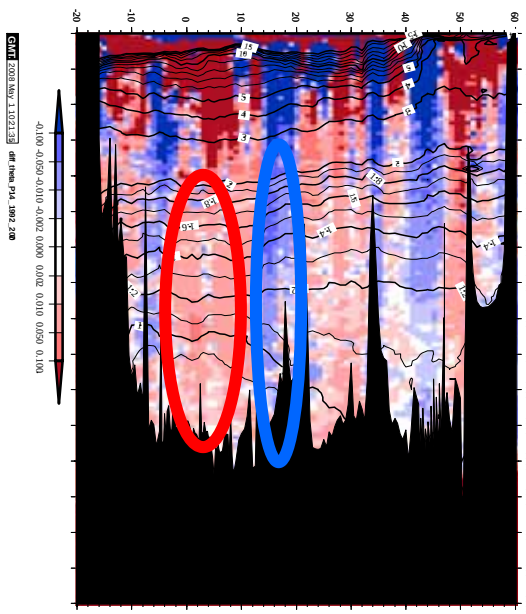


Silicate, Nitrate and dissolved oxygen differences
in terms of micro mol kg^{-1} along P14N line in 2007 and 1993



Silicate difference and concentrations along P14 in 2007 and 1993





⊿theta field

Gradient decrease observed. This suggest that low silicate/ high DO CDW comes less.

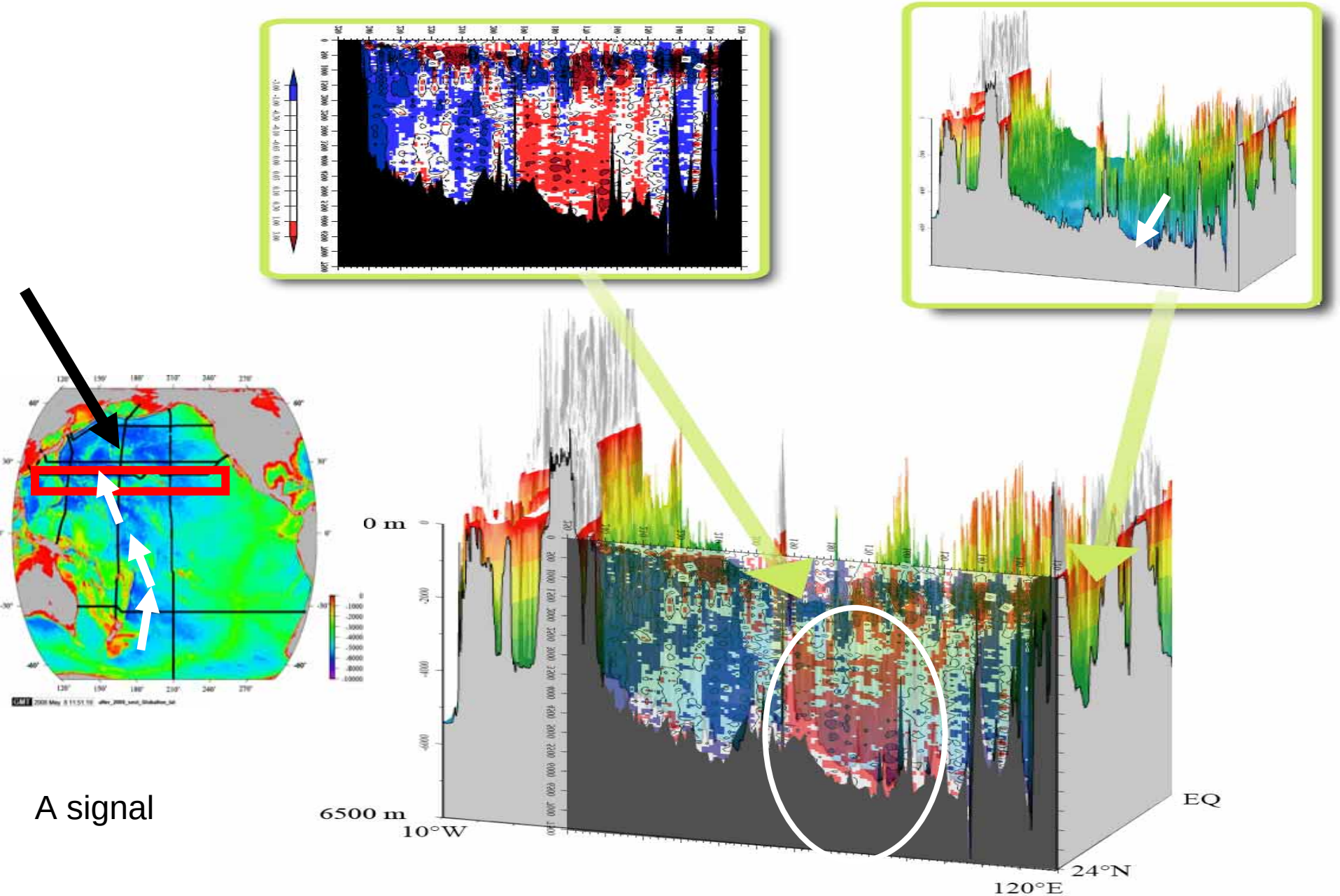
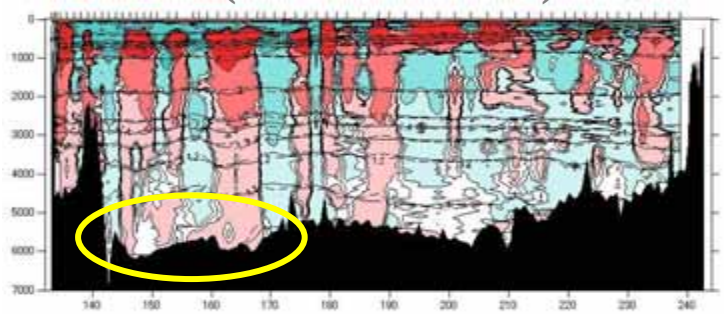


Fig. 9 Differences of silicate concentration along P3 line (Fig. 6-2) over 3-D topography at the region 24°N-EQ, 120°E-10°W. (View from north)

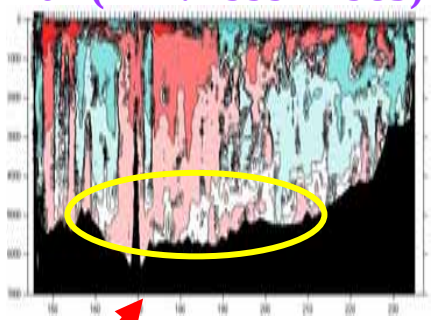
Pioneering findings of abyssal warming （0.01～0.003˚C）

in recent years in the Pacific Ocean

P02 (30N: 2004 - 1994)



P01 (47N: 1999 - 1985)



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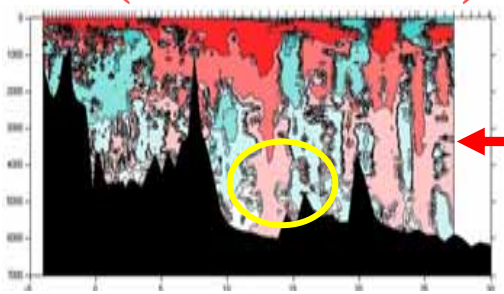
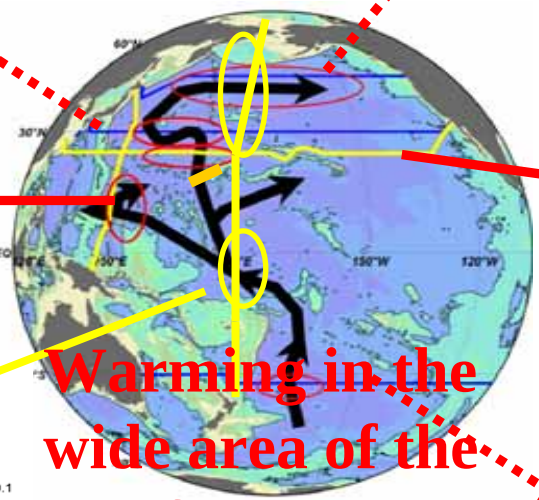
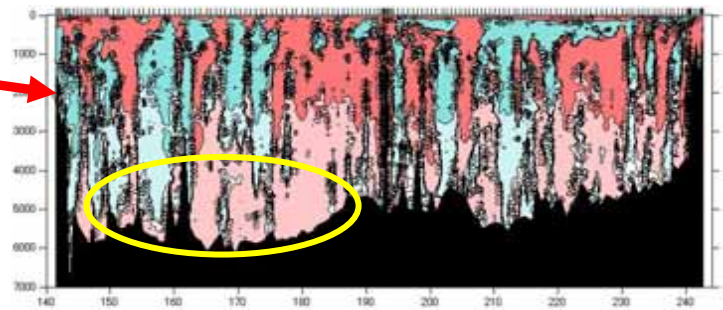
P10 (149E: 2005 – 1993)

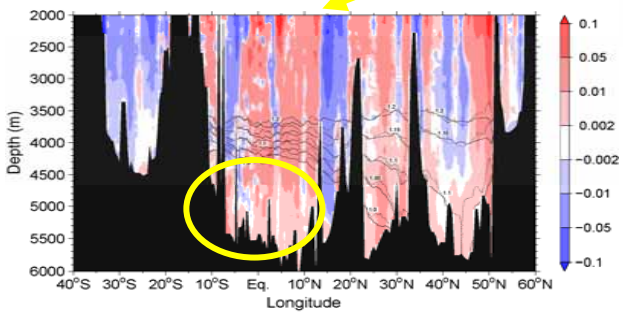




P03（24N: 2005/6 - 1985)

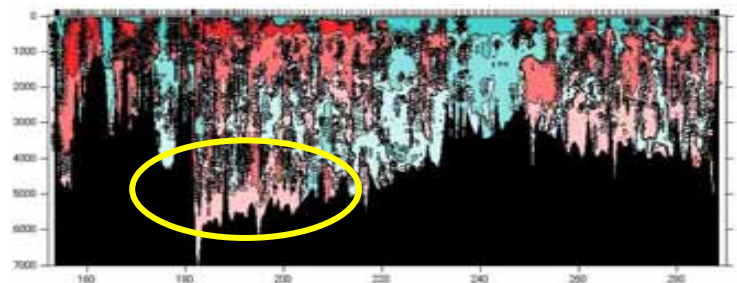


P14(2008-1993）



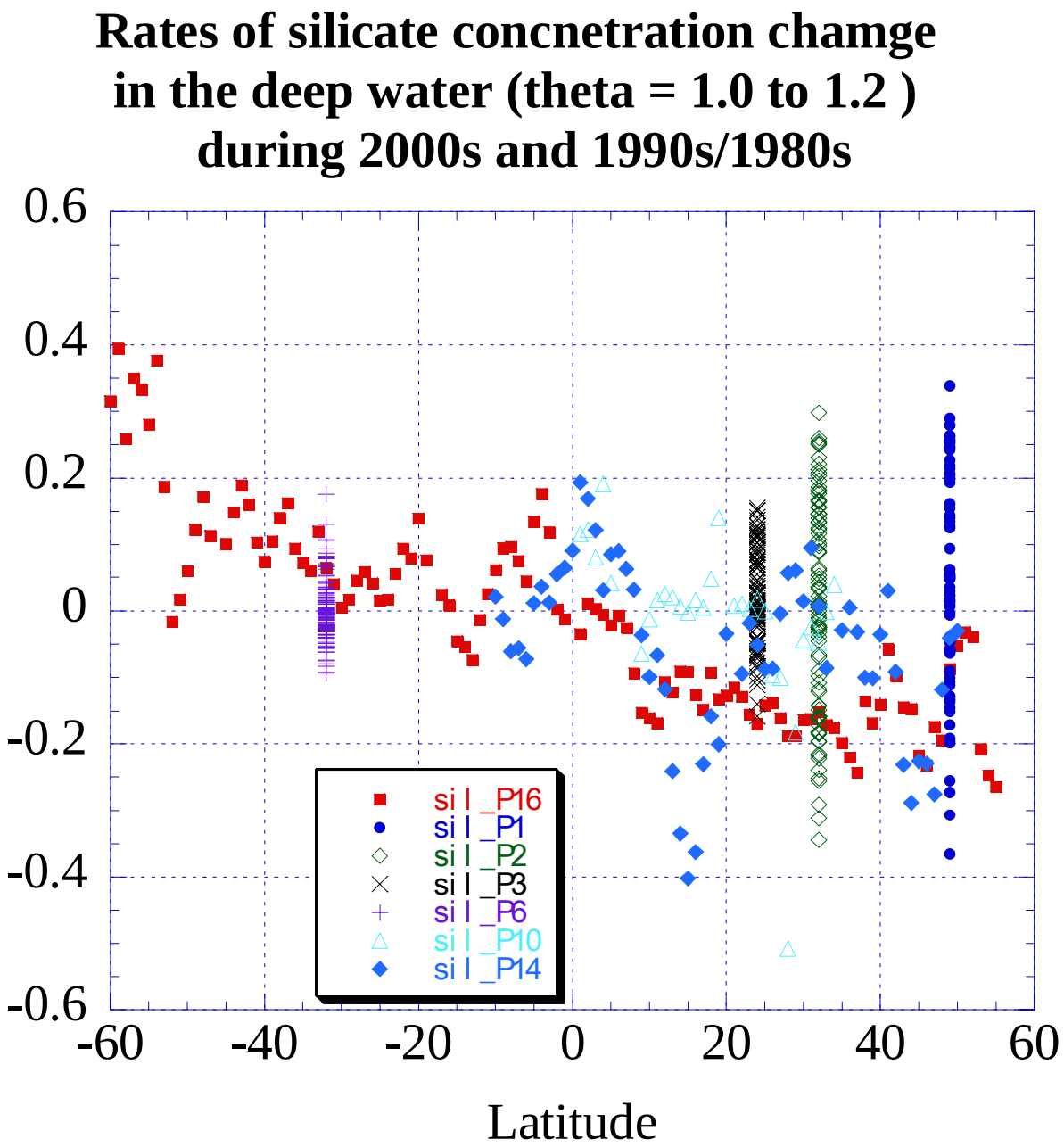
Warming in the wide area of the Pacific Ocean. The signal is strong in the South Pacific

P06 (32S: 2003 - 1992)



sec_ID	duration /year	silicate offset /micro mol kg	Dissolved oxygen offset /micro mol
P01	8	0	-0.8
P02	10	-2	-2
P03	20	0	-1.6
P06	16	-1	-0.3
P10	12	1.2	0
P14	15	-5	0
P16	14	-3	0

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

sec_ID	duration /year	silicate offset /micro mol kg	Dissolved oxygen offset /micro mol
P01	8	0	-0.8
P02	10	-2	-2
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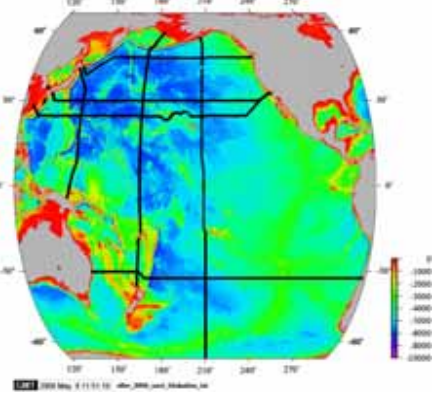
P10	12	1.2	0
P14	15	-5	0
P16	14	-3	0



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