How does expanding hypoxia affect the nutrient budget of the subarctic Pacific?

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Hypoxia occurs for humans at high altitude

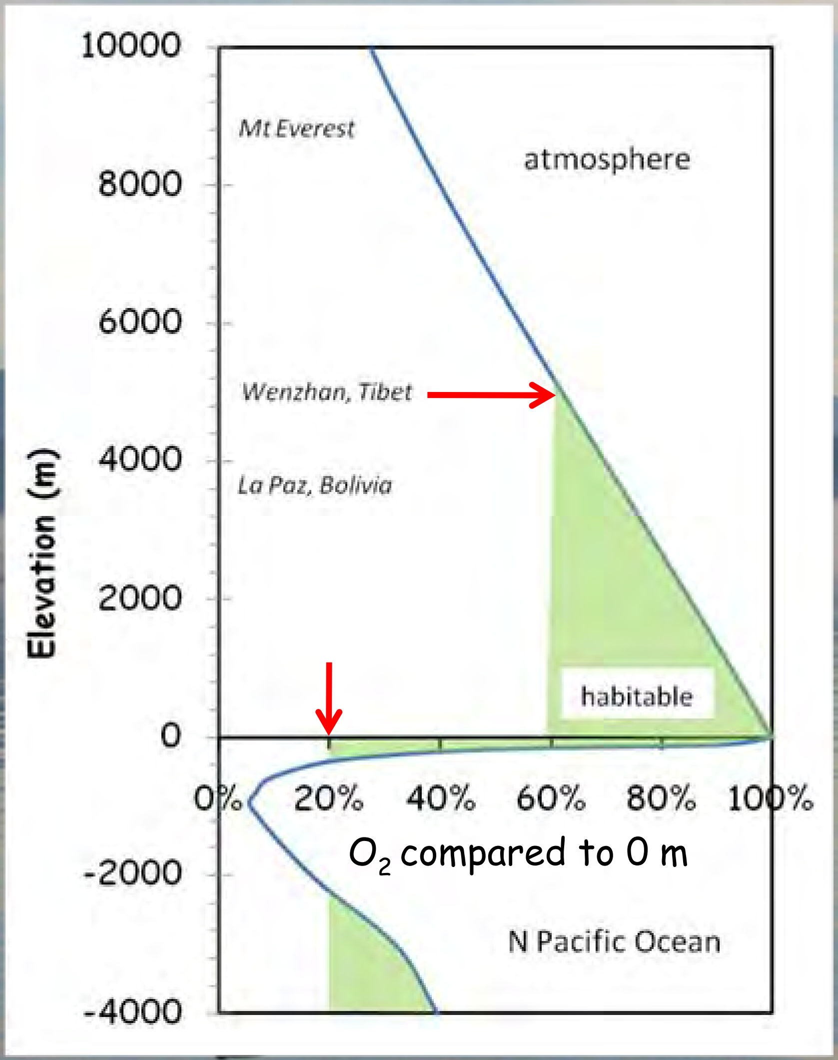
Oceanic hypoxia <u>can</u> occur at shallow depths

I suggest oxygen (next to light) is the strongest habitat delimiter in the N Pacific

Coping with hypoxia:

Respirator, evolution (Tibetans)

Slender bodies, Increased gill area



Outline:

1. Mixed layer nutrient <u>variability</u>

2. Subsurface nutrient and oxygen <u>trends</u>

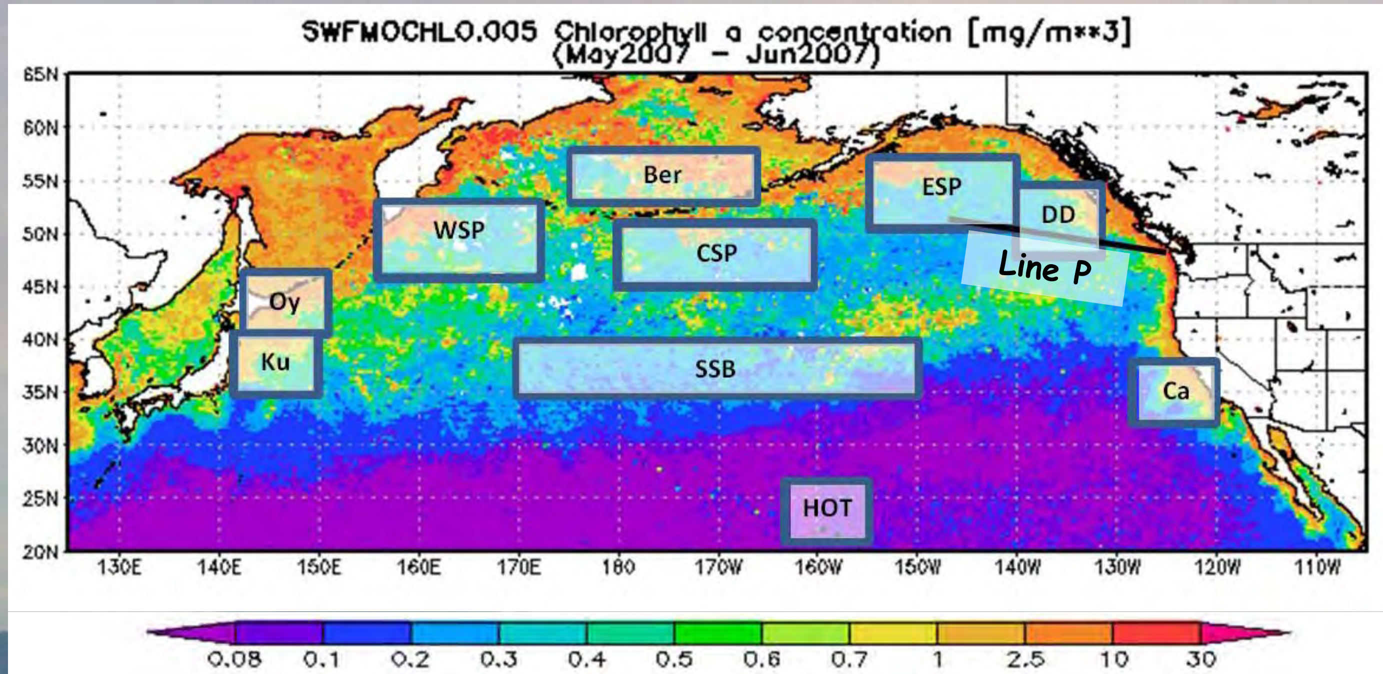
3. Summary of findings

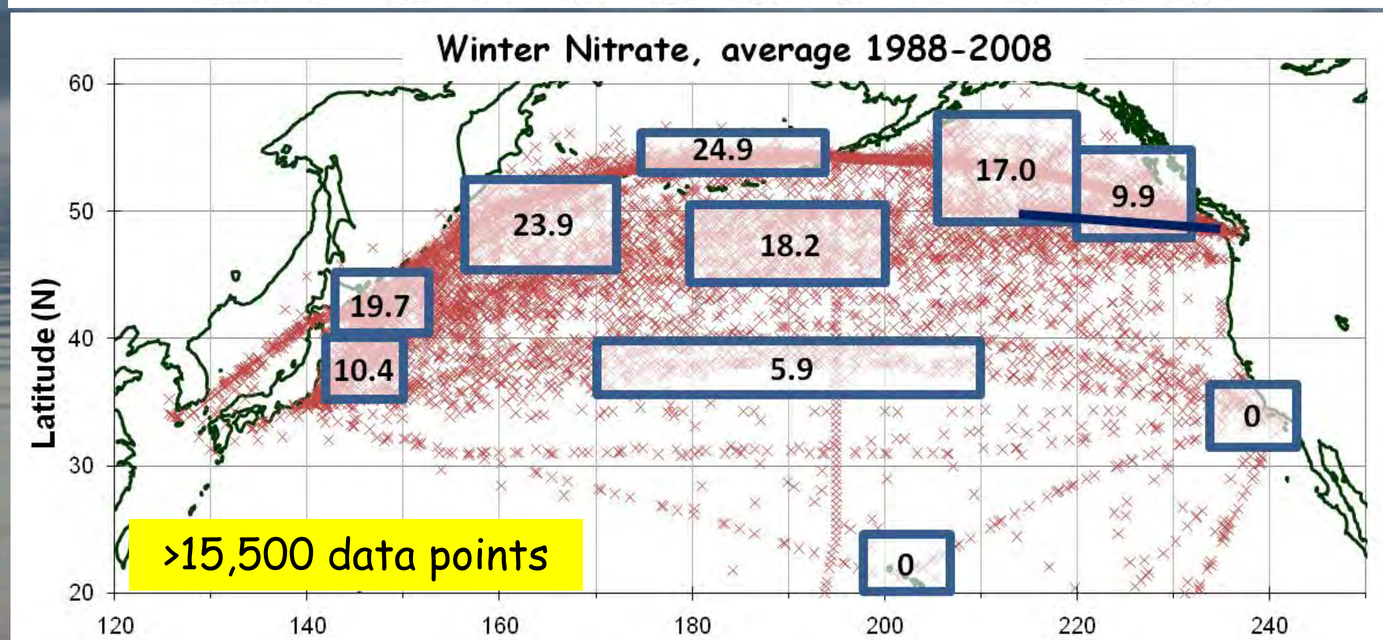
With thanks to CalCOFI, HOT, WOCE, Line P and A-line for posting data on-line

1. Mixed Layer Nutrients

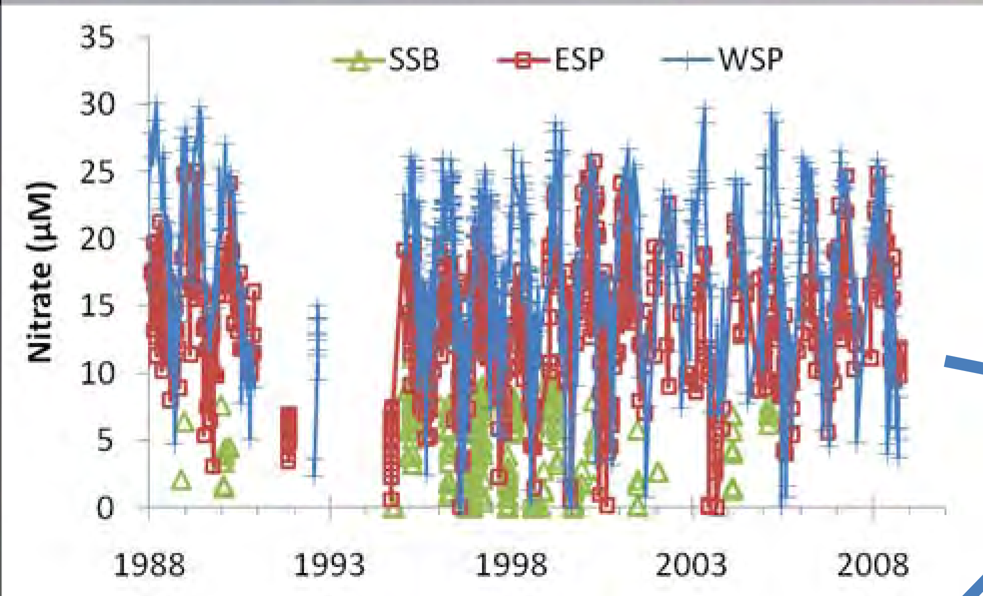
Domains:

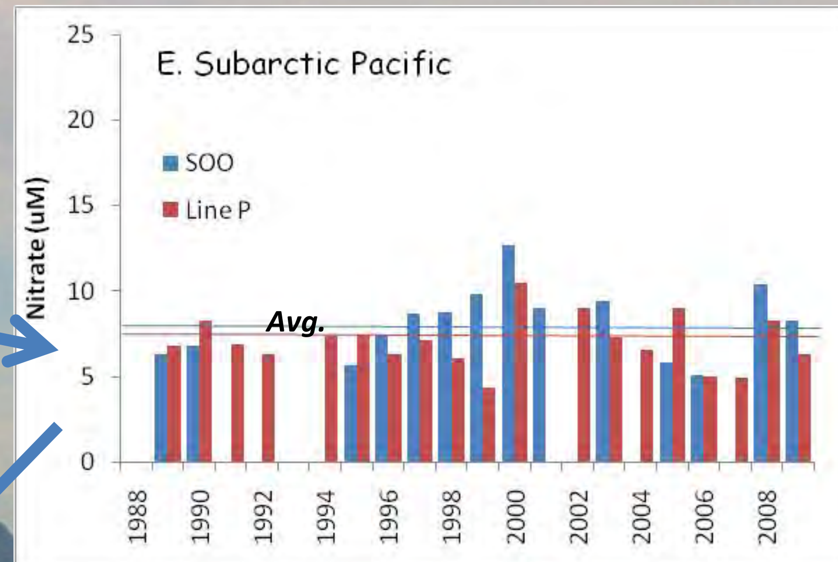
Kuroshio
Oyashio
Western Subarctic
Bering Sea
Central Subarctic
Eastern Subarctic
Dilute Domain
Subarc./Subtrop. Boundary
California (CalCOFI)
Hawaiian Ocean T-S

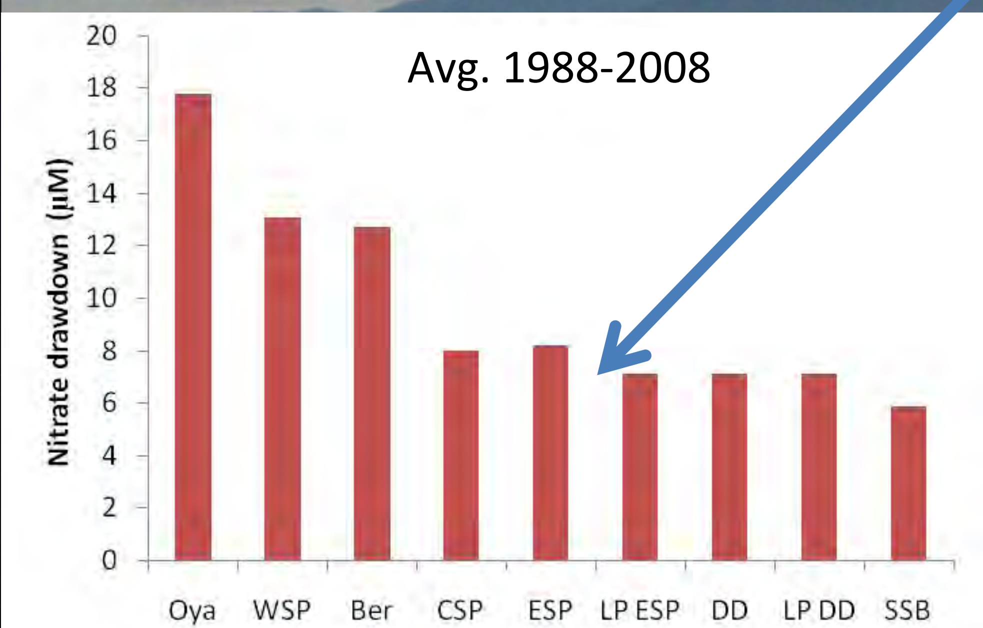


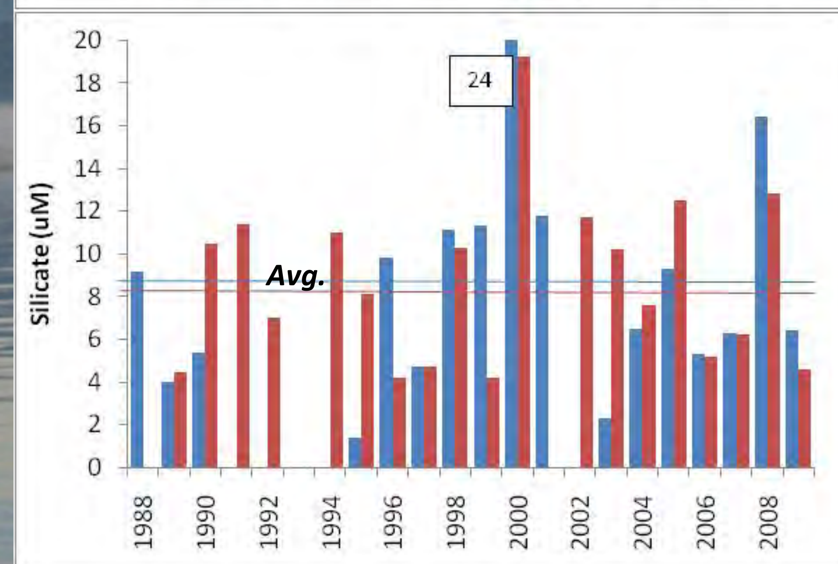


Seasonal nutrient drawdown

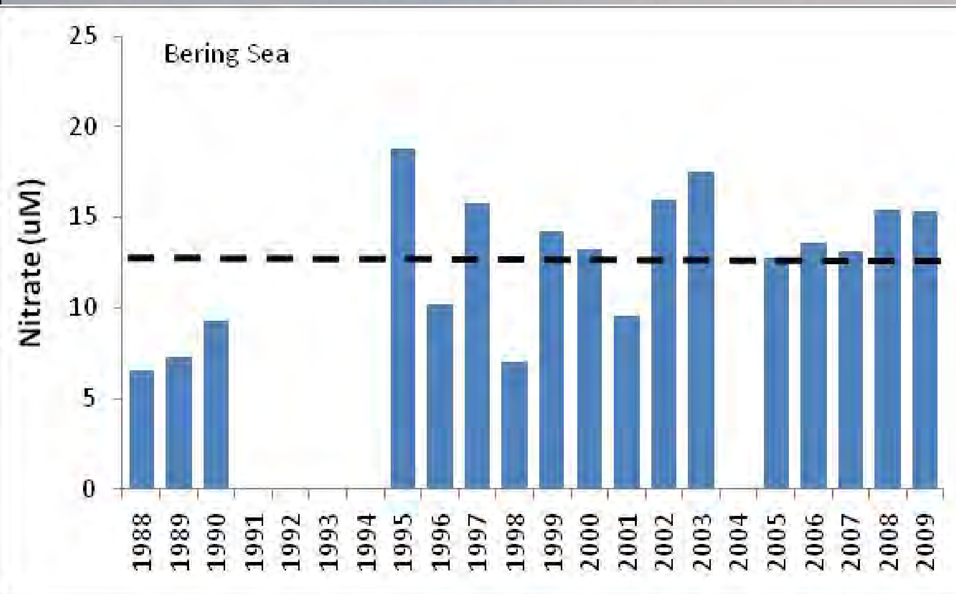


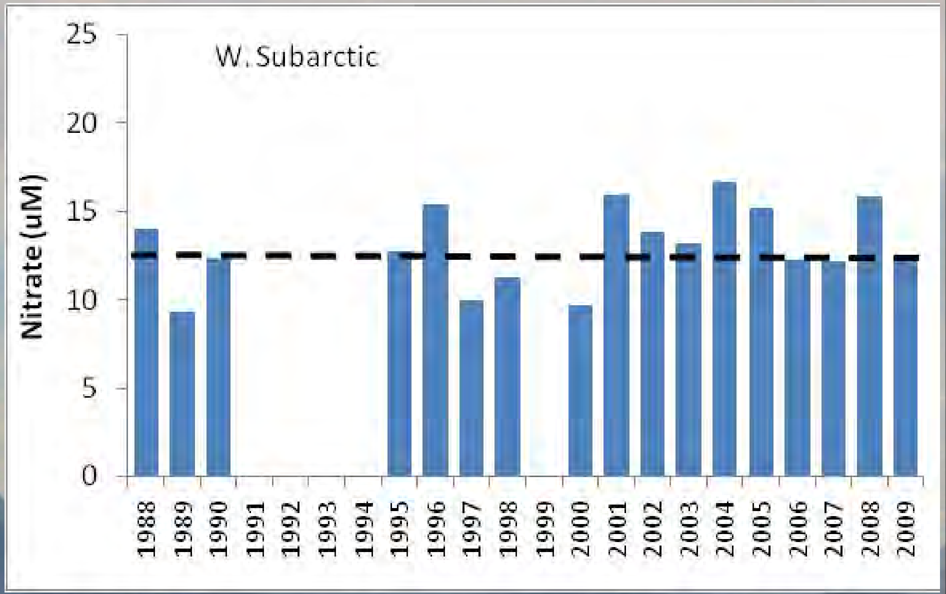


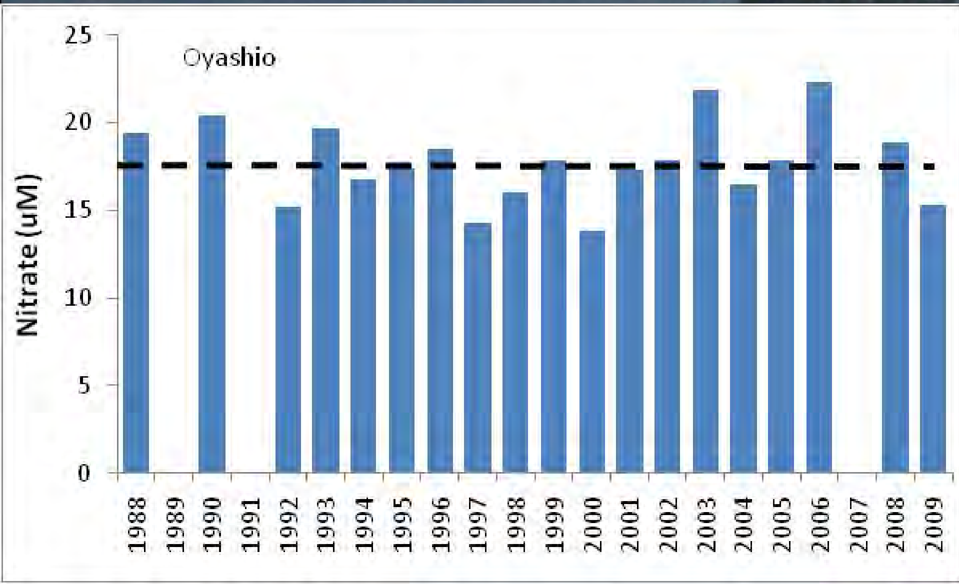


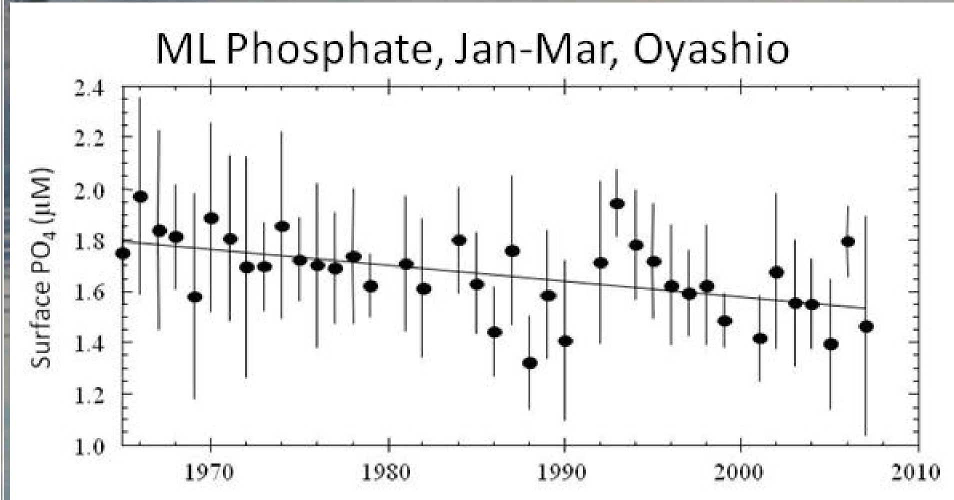


Nutrient variability



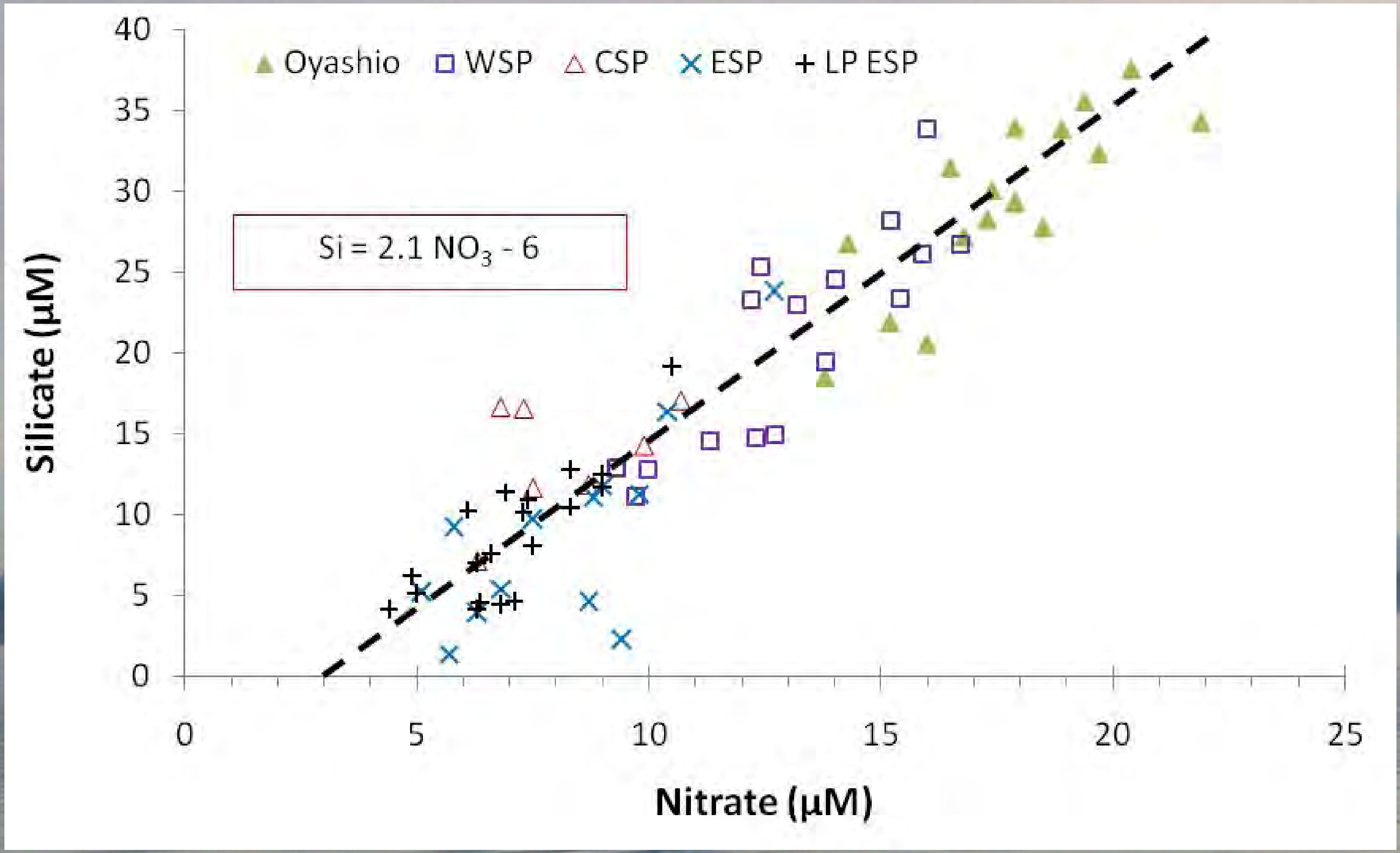






Ono et al., 2002; Chiba et al., 2010

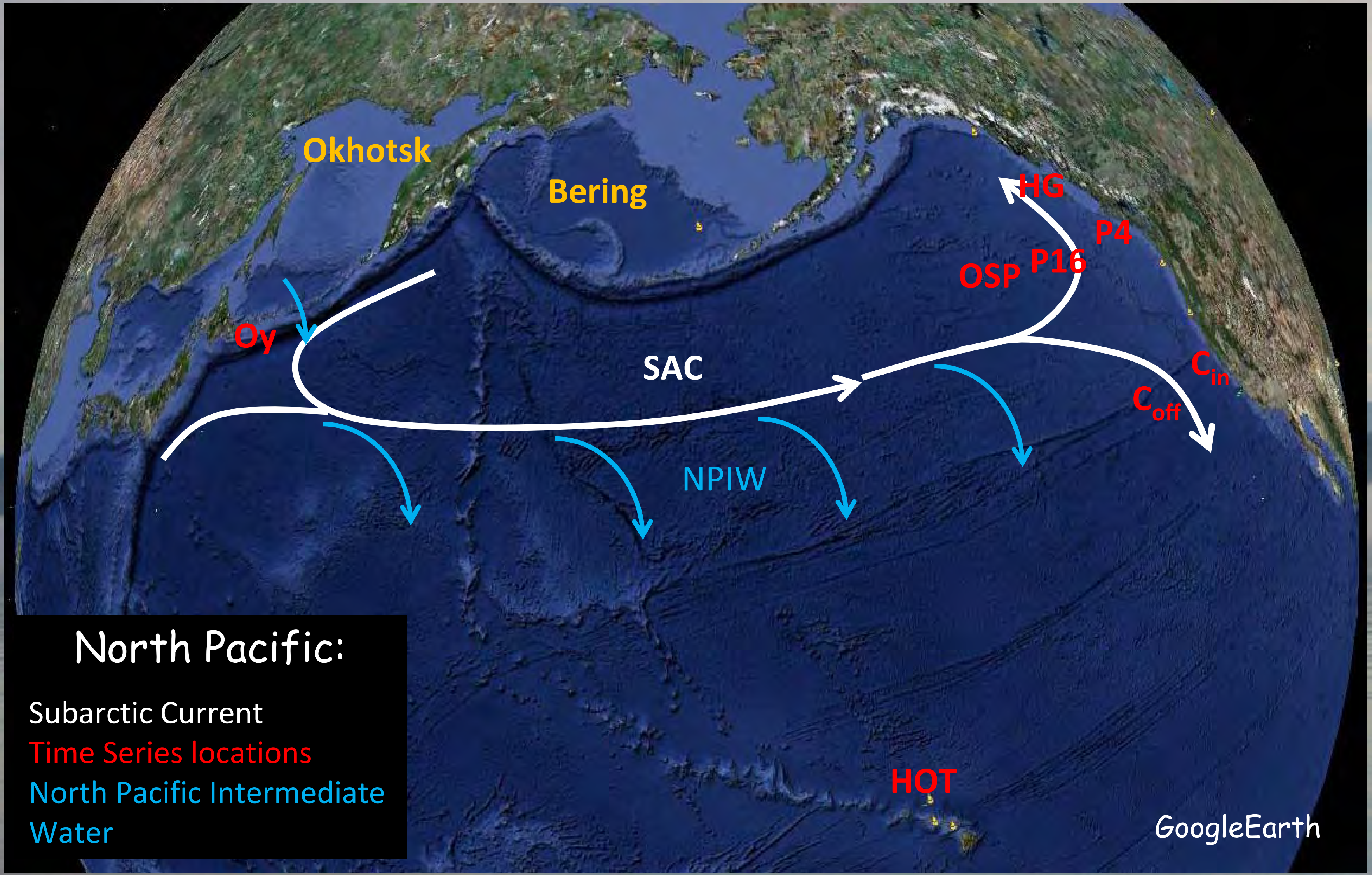
A striking relationship between NO_3 and Si



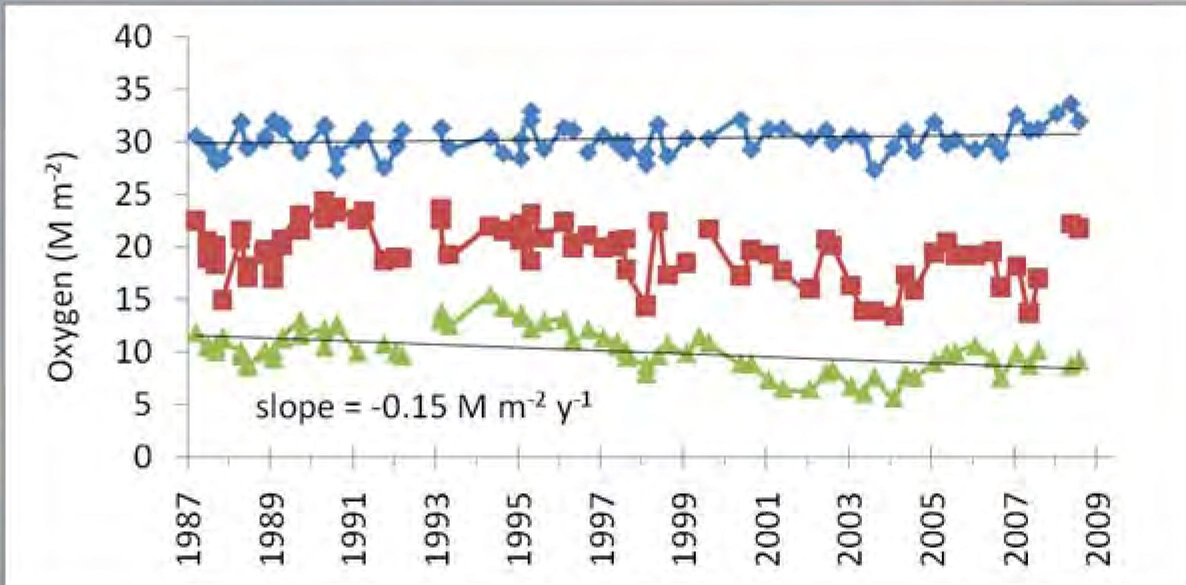
Apparently, New Production (nitrate based algal growth) cannot be directly equated to export production (diatom growth).

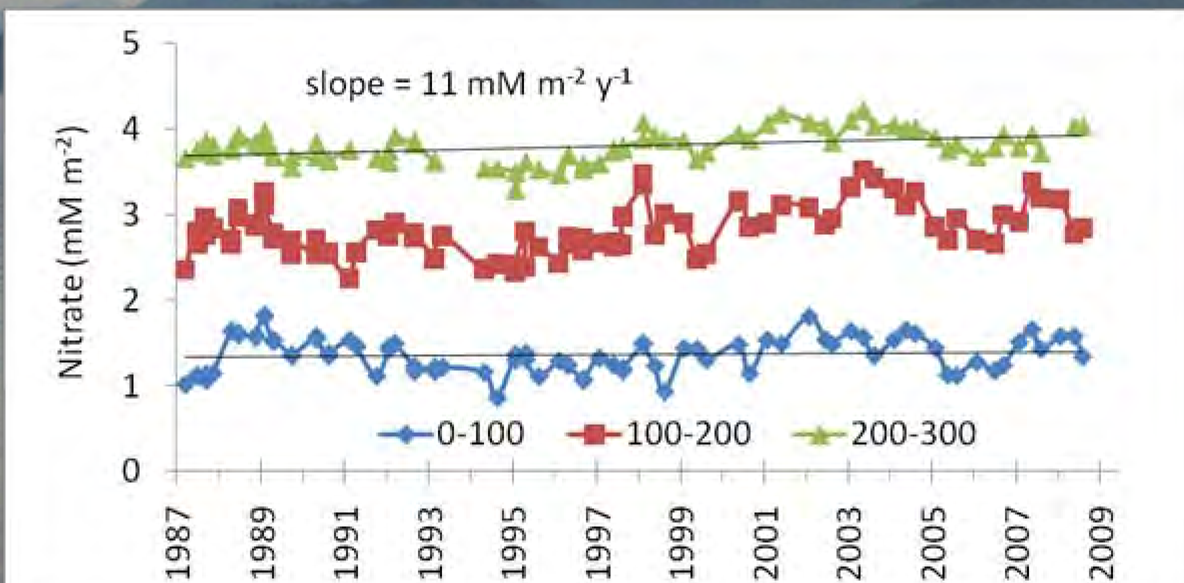
~3 µM NO_3 fuels small plankton, any excess supports diatom growth

2. Interior Ocean Trends – Time-Series Data



Ocean Station P as an example of trend analyses

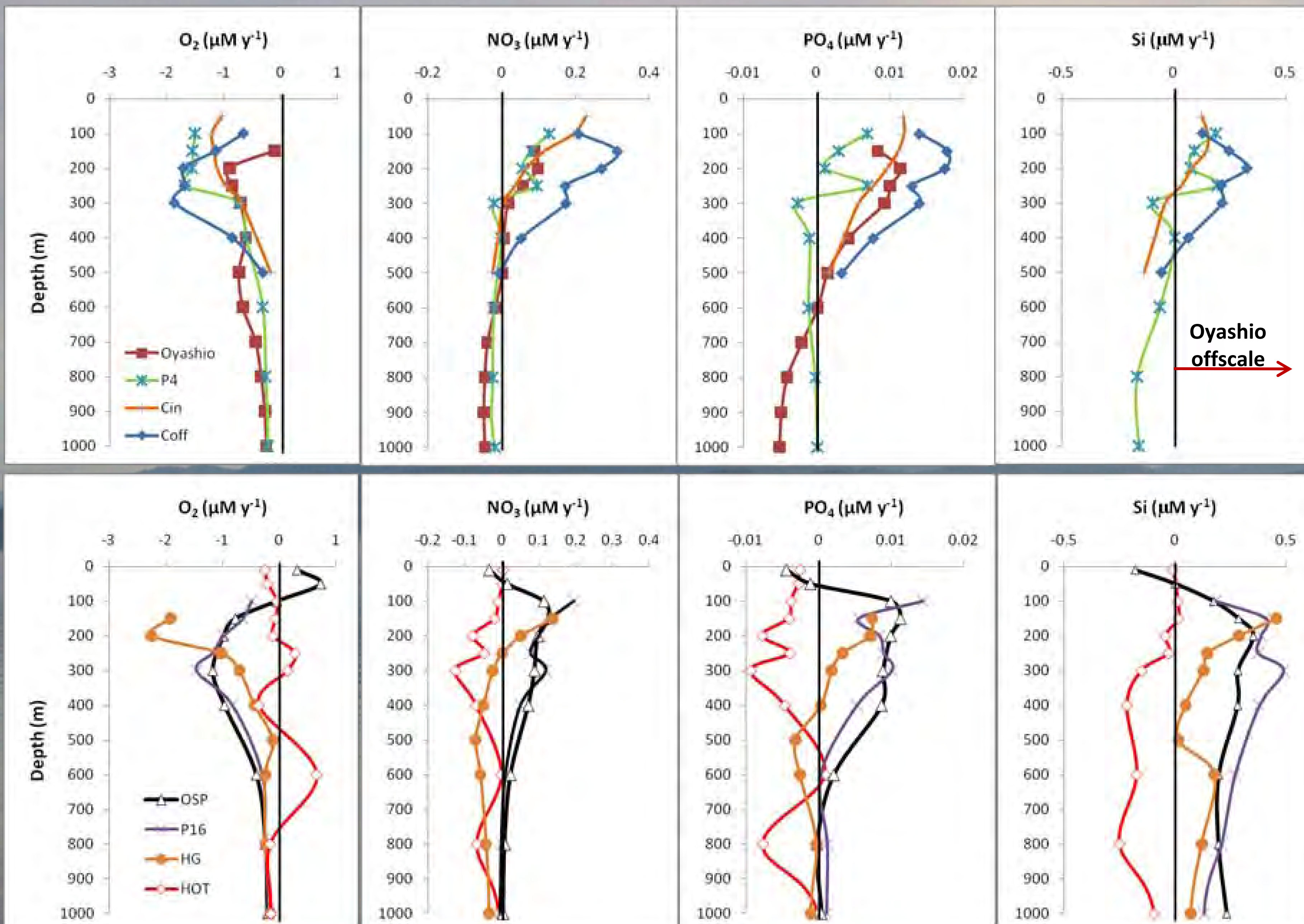




At St P, oxygen is declining and nitrate increasing a ratio of

100-200 m 8.3:1
200-300 m 13:1

North Pacific Trends – Oxygen and Nutrients



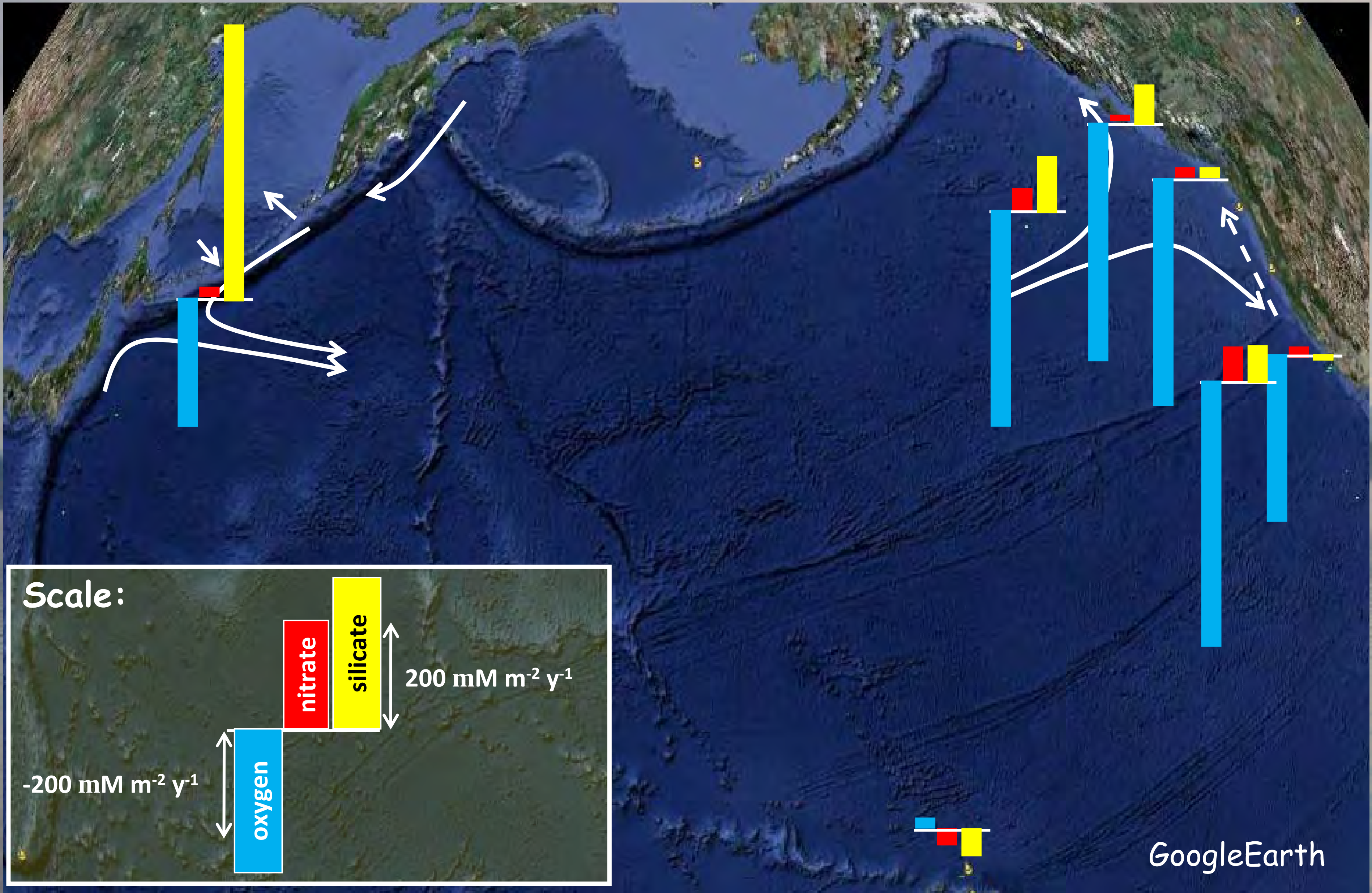
Trends at N Pacific Time Series Sites over the past 20-25 years

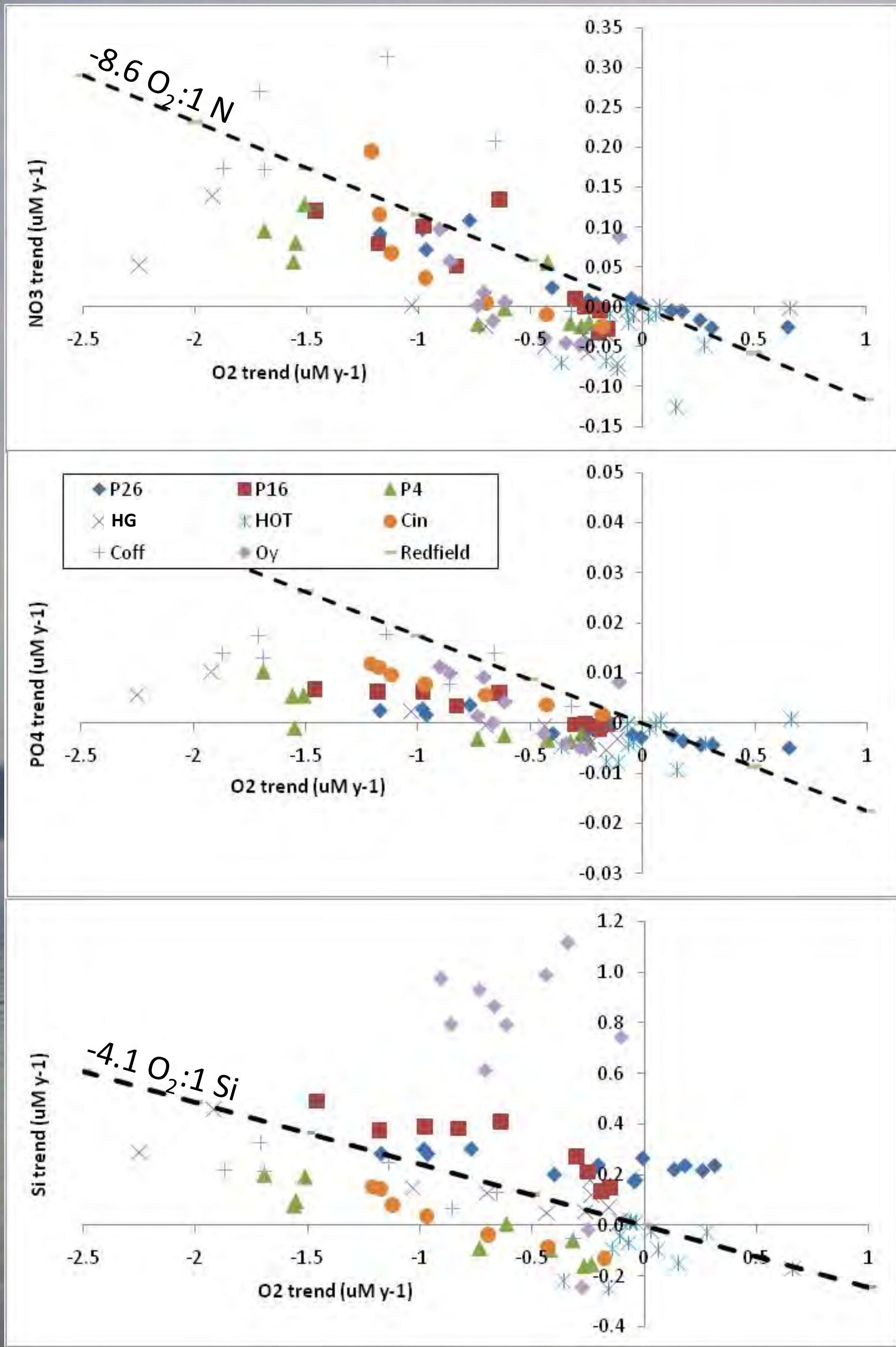
Station (Btm ML)	O_2	NO_3	PO_4	Si	O/N	N/P	O_2	NO_3	PO_4	Si	O/N
	Bottom of ML to 500 m, mmol m^{-2} y^{-1}						Btm of ML to 1000 m, mmol m^{-2} y^{-1}				
Oya (150)	-242	12.1	2.47	293	20.0	4.9	-464	-4.93	1.20	612	38.3
OSP (100)	-346	32.7	3.43	108	10.6	9.5	-497	41.8	4.18	218	11.9
P16 (100)	-360	35.2	2.81	152	10.2	12.5	-516	38.8	3.47	267	13.3
P4 (100)	-410	12.2	0.37	13.4	33.6	33	-567	2.4	0.13	-43.4	236
HG (150)	-314	-4.2	0.42	48.5	*n/a*	*n/a*	-419	-28.4	-1.49	108	*n/a*
C_{in} (50)	-354	24.6	3.19	6.1	14.4	7.7					
C_{off} (100)	-485	61.1	4.76	62.7	7.9	12.8					
HOT (100)	13.2	-24.2	-2.02	-44.2	0.5	12.0	48.5	-42.4	-3.67	-141	*n/a*

Red denotes the effects of denitrification on trends and ratios

Trends in O_2, NO_3 and Si over the past ~25 y

(bottom of the mixed layer to 500 m)



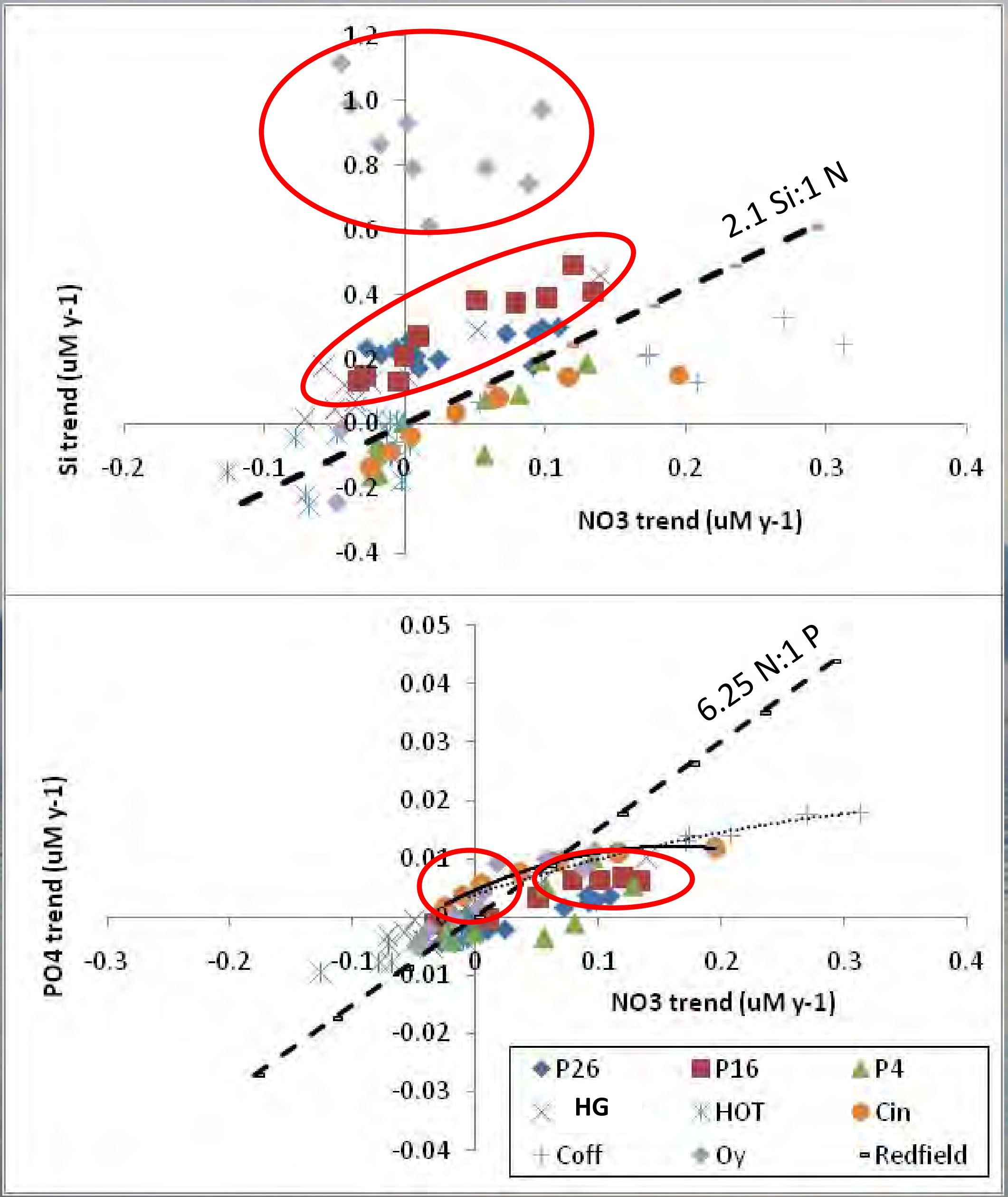


Oxygen–nutrient correlations - subsurface ocean

In general:

- oxygen is being lost from subarctic waters and nutrient levels are increasing
- nitrate and phosphate losses, compared with O_2, are less than Redfield ratios due to the faster turnover of N and P compared with C
- subtropics are losing Si, subarctic is gaining
- an unidentified Si source has dramatically increased Si levels in the Oyashio region

Nutrient trend correlations – subsurface ocean



In general:

- Si is increasing in subarctic waters suggesting an enhanced source or reduced sink in the NW Pacific and its marginal seas with effects being seen downstream.

- N and P do not track Redfield ratios in specific regions:

1. In coastal waters where denitrification is occuring
2. In open ocean where data suggests a somewhat faster turnover of P than N

3. Summary:

- Si vs NO_3 drawdown in the ML suggests nitrate is not directly proportional to export production
- Scant evidence of declining nutrient supply to the mixed layer
- **But nutrient storage in the ocean interior is increasing. Source?**
- An unidentified source of Si is enriching Oyashio waters, with downstream effects evident at OSP. Okhotsk?
- Si levels are declining in subtropical waters according to HOT data. Could this be the result of reduced inputs from major rivers (e.g. Changjiang, Columbia, Colorado...)?
- **Time-series data have the internal consistency to allow us to observe changes in the interior waters of the N. Pacific**