Ocean-Climate Coupling: Biogeochemical Responses in the Tropical Pacific During 1950-2005

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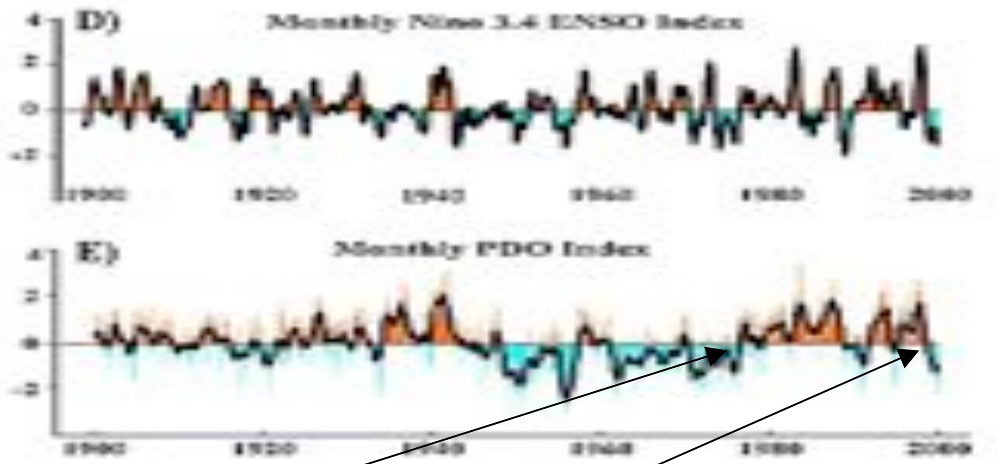
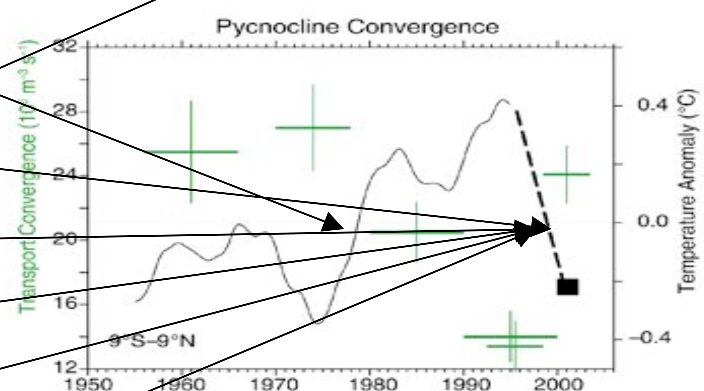
Scientific Background

- Climate Variability
  - ENSO
  - PDO



- McPhaden and Zhang (2002): circulation slows down in late 1970's.
- McPhaden and Zhang (2004): circulation rebounds post mid-1998.
- Chavez et al. (2003): biological regime shift in late 1990s.
- Wang et al. (2005): zooplankton increase post mid-1998.
- Feely et al. (2006): carbon chemistry change post mid-1998.
- Behrenfeld et al. (2006): NPP-climate coupling.



Regime shifts: 1977 (RS1), 1997/98 (RS2)

- ❖ Obs: physics (RS1, RS2), fish (RS2), pCO2 (RS2)
- ❖ Model: zooplankton/ecosystem (RS2).

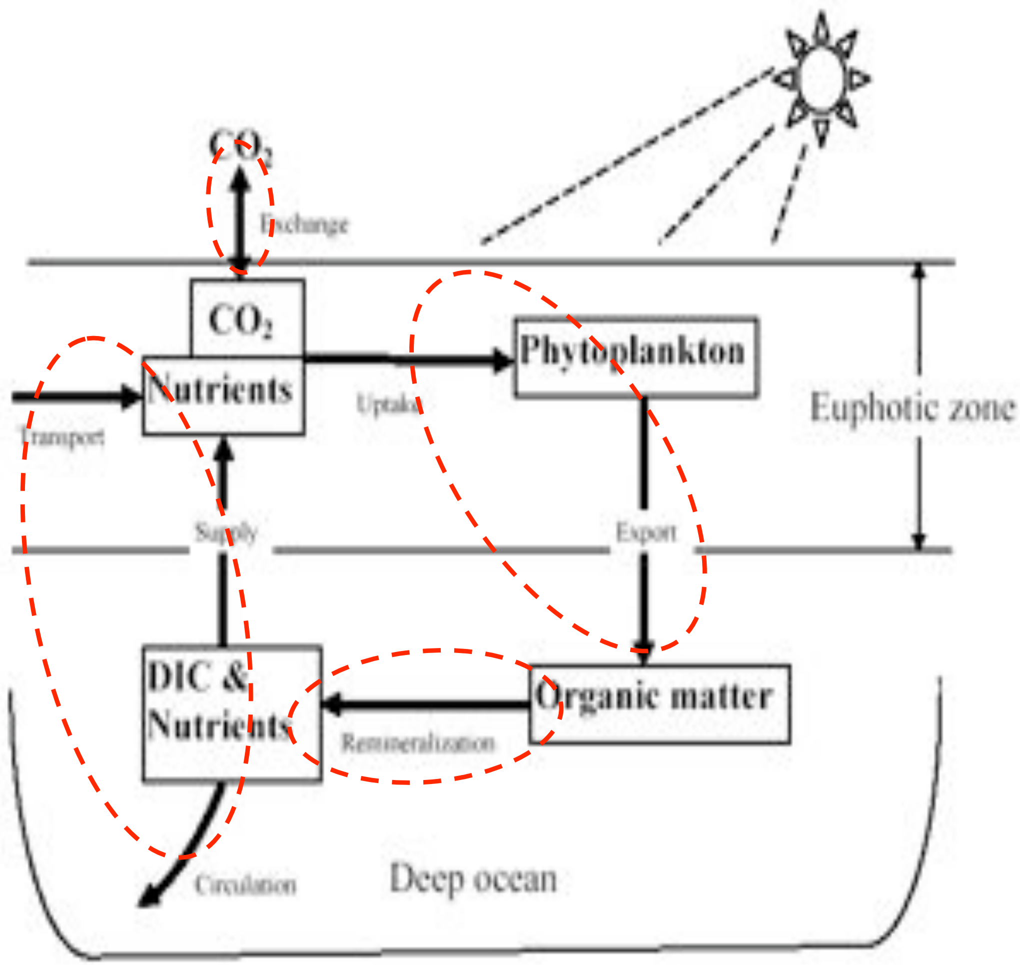
A big question

- ❖ Regime shifts in biogeochemistry?

Modeling approach

- ❖ Model validations:
  - ➢ chl, C:chl, phyto, zoo,DON,PON,PP,NP,NCP,pCO2,air-seaCO2 flux.
  - ➢ ENSO variability
- ❖ 50-year analyses of physical & biogeochemical parameters

C&N cycles in the ocean



A OGCM-ecosystem-C model

OGCM:

Gent & Cane (1989)

Murtugudde et al.(1996)

Ecosystem model:

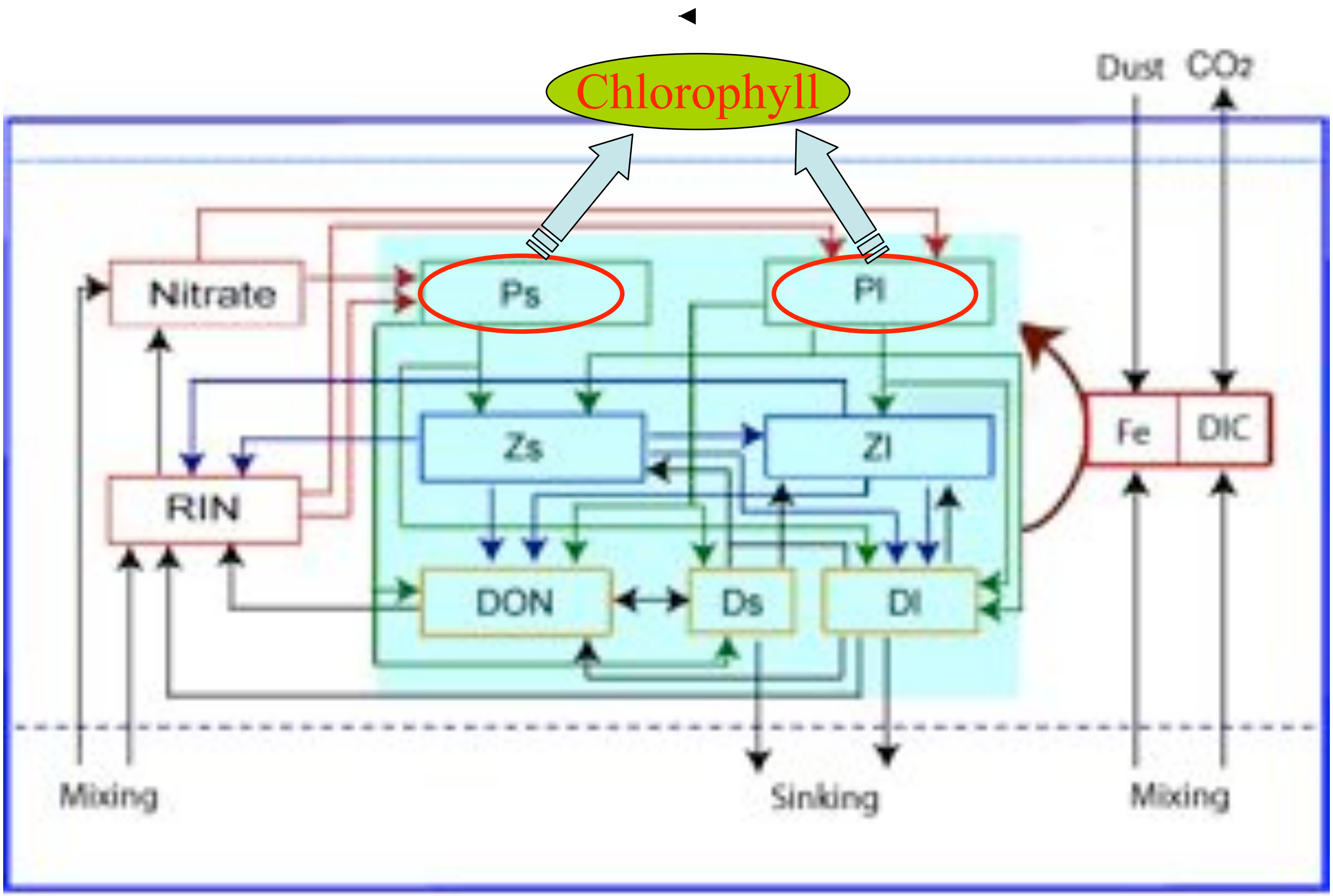
Christian et al.(2001)

Wang et al. (2006a,2007)

C chemistry model

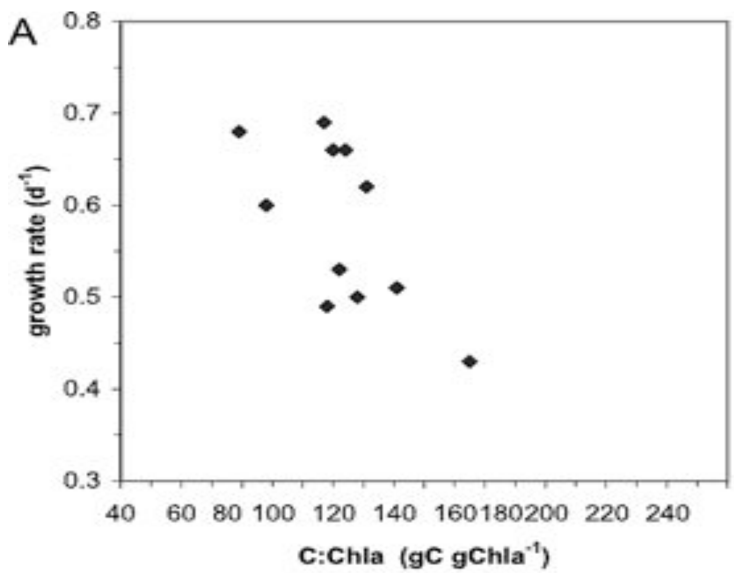
Wang et al. (2006b)

Dynamic Ecosystem-Carbon Model



The surface C:Chl ratio increases with decreased growth rate:

Le Bouteiller et al. (2003)



- Linear relationship between Chl:C ratio (θ) and growth rate (μ*) under similar light conditions:

$$\theta = \mu^* \theta_I + \theta_{\min}$$

- Light regulation on Chl:C ratio under non-nutrient-limitation conditions (**Geider et al. 1996**):

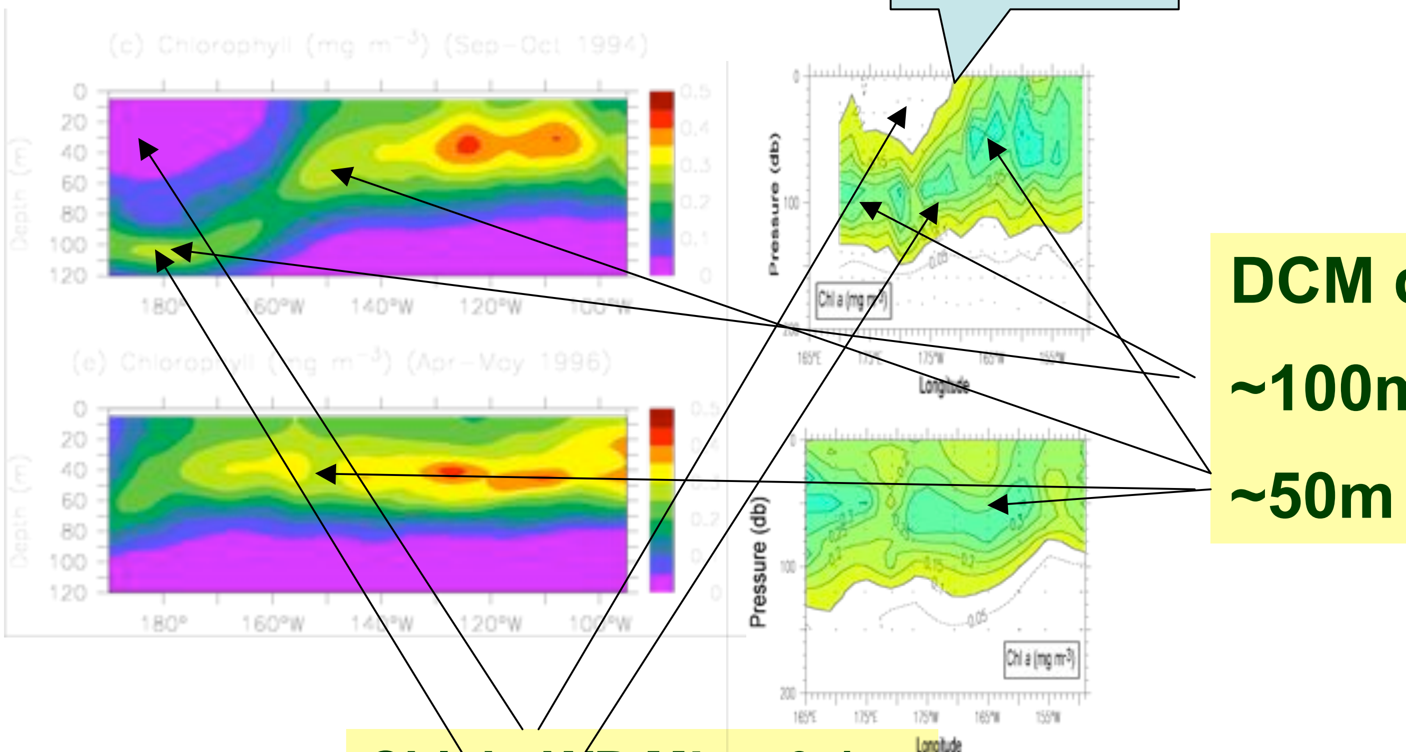
$$\theta_I = \frac{\theta_{\max *}}{1 + \theta_{\max *} \alpha I / 2 P_{\max}^C}$$

$$\theta = \mu_0 e^{k_T T} g(N, Fe) \left(\frac{\theta_{\max *}}{1 + \theta_{\max *} \alpha I / 2 P_{\max}^C} \right) + \theta_{\min}$$

$$g(N, Fe) = \min\left[\frac{NO_3}{K_{NO_3} + NO_3} \left(1 - \frac{RIN}{K_{RIN} + RIN} \right) + \frac{RIN}{K_{RIN} + RIN}, \frac{Fe}{K_{Fe} + Fe} \right]$$

Chl:C = f(I,N,T)

Data



DCM depth:

~100m in WP

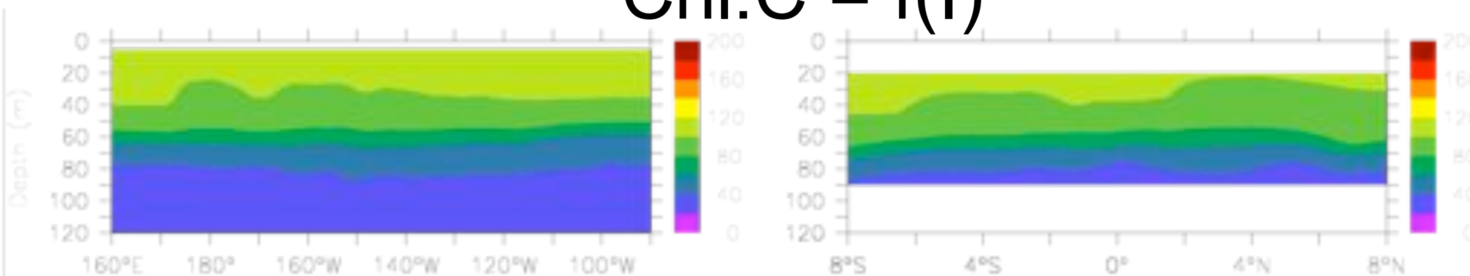
~50m in CEP

Chl. in WP ML: <0.1

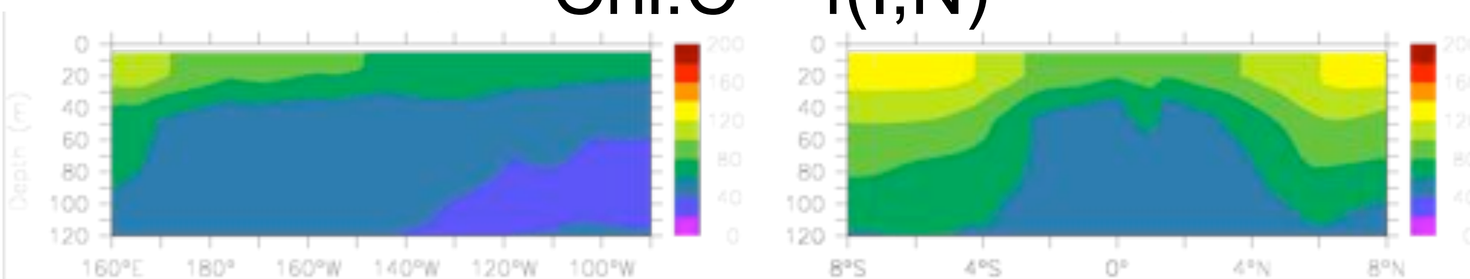
Chl. at DCM: 0.2-0.3

Vertical C:Chl ratio in 1996

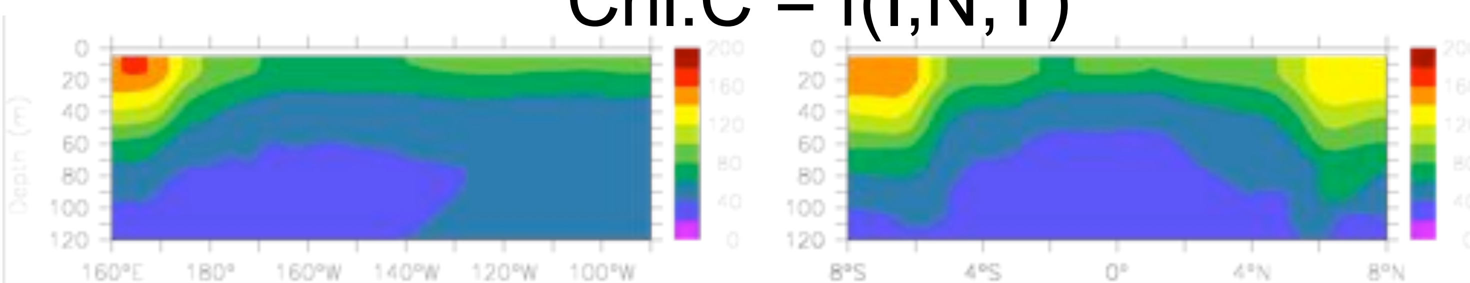
Chl:C = f(I)



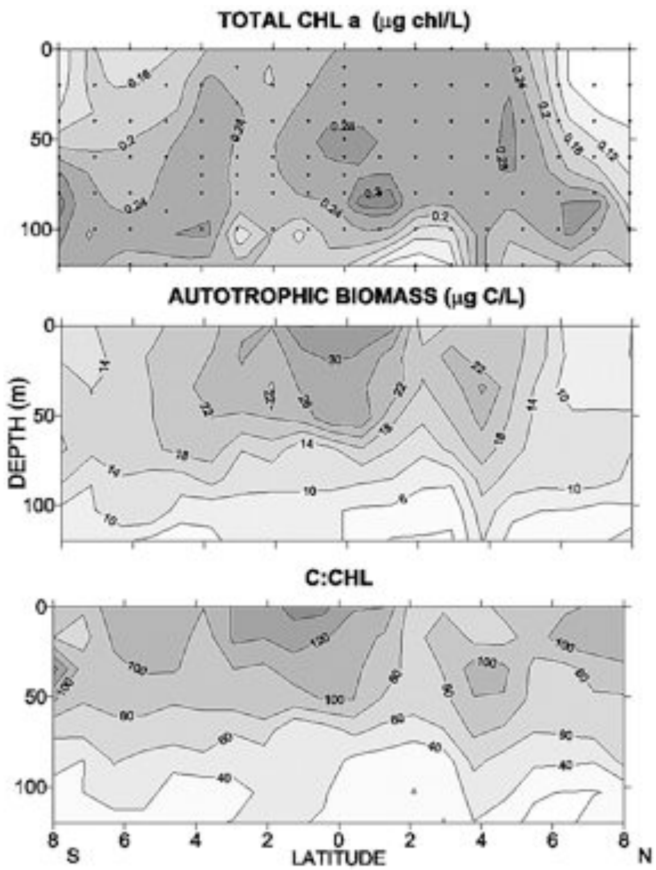
Chl:C = f(I,N)



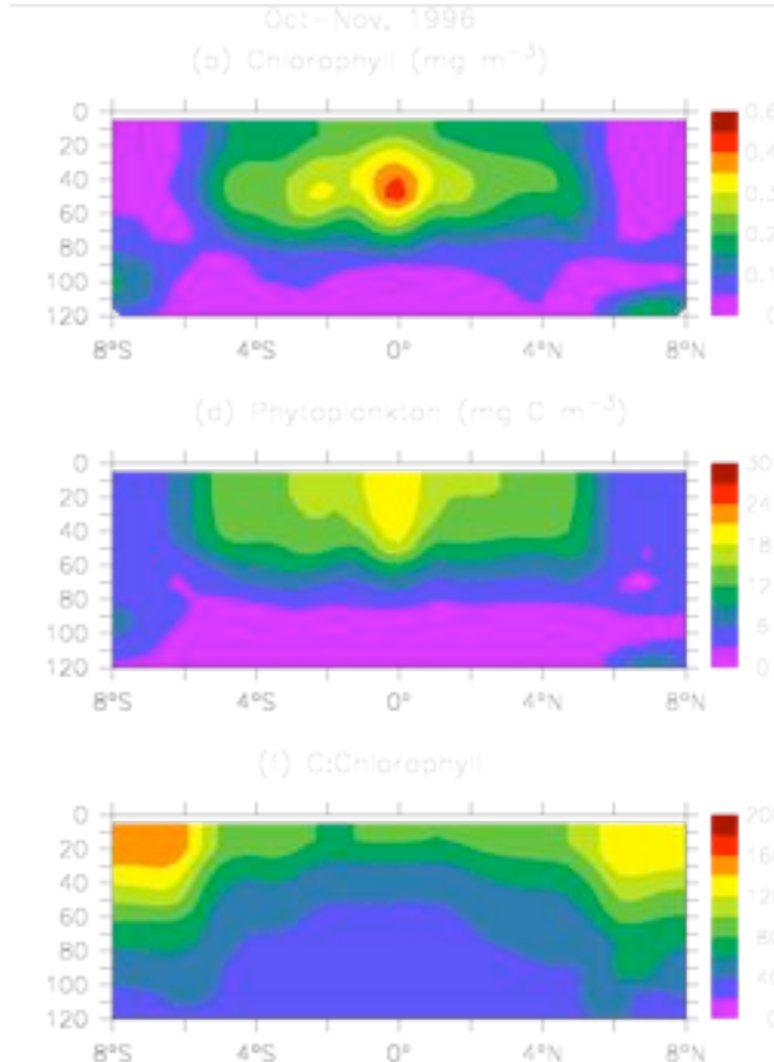
Chl:C = f(I,N,T)



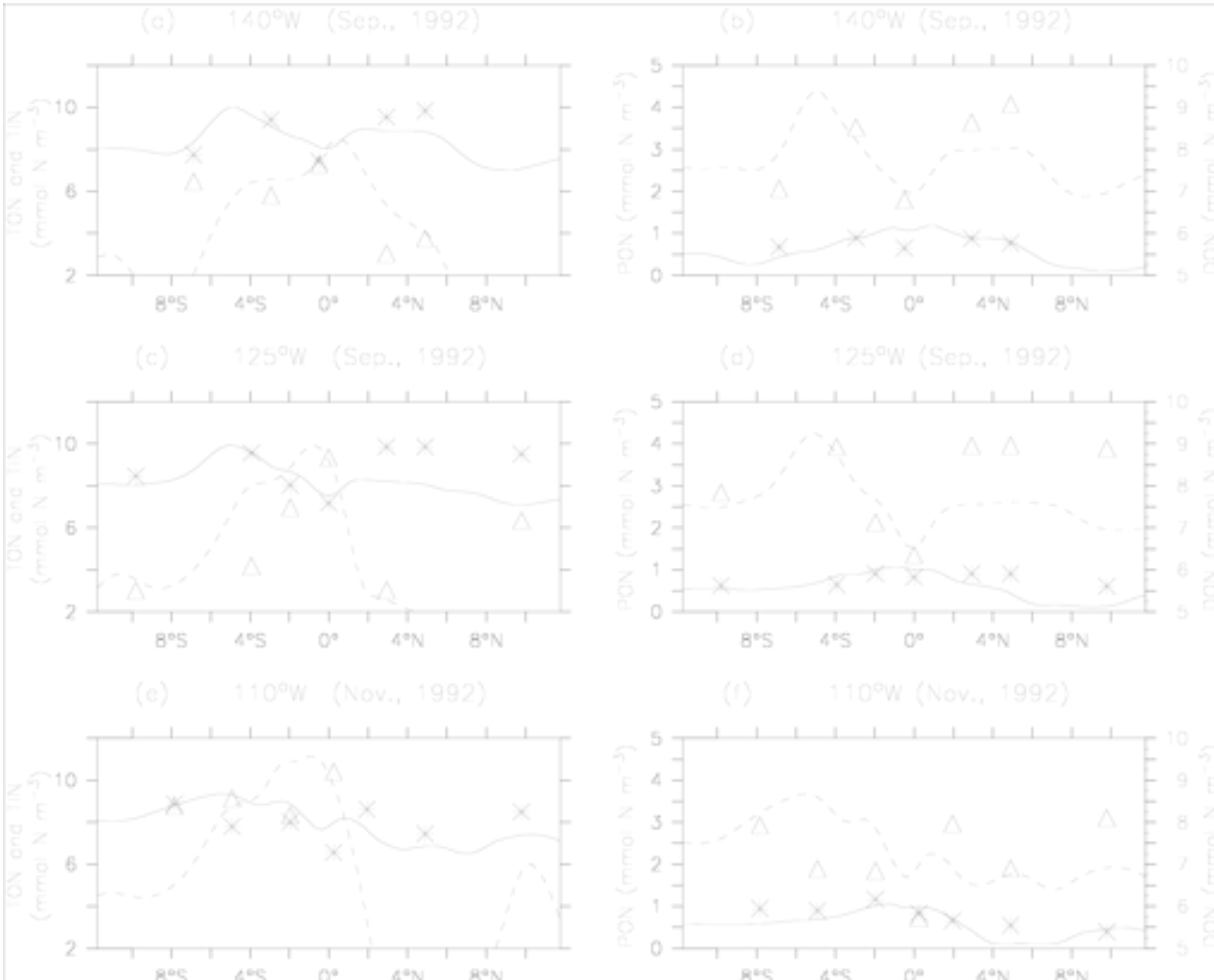
Brown et al. (2003)



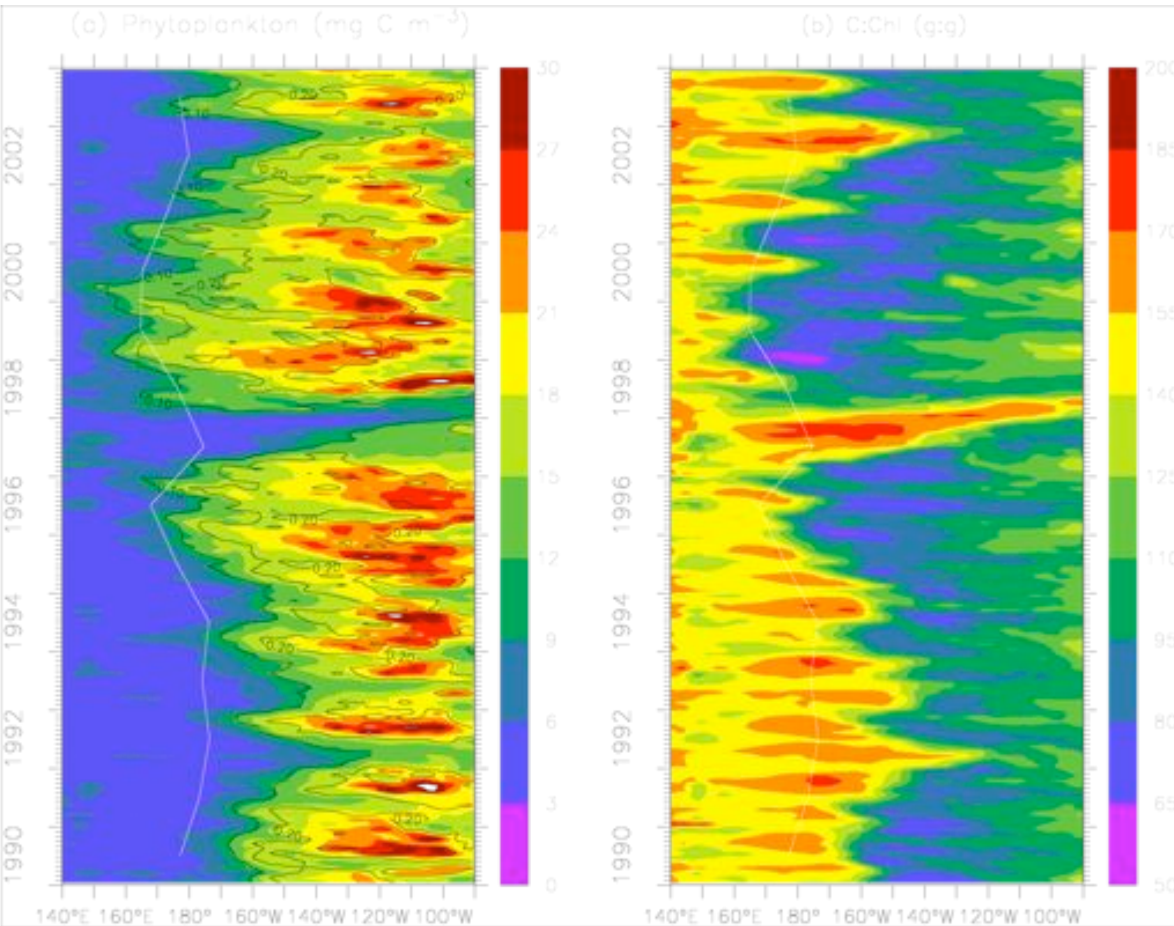
Chl:C=f(I, N, T)



Model vs. data: TON, TIN, DON, PON



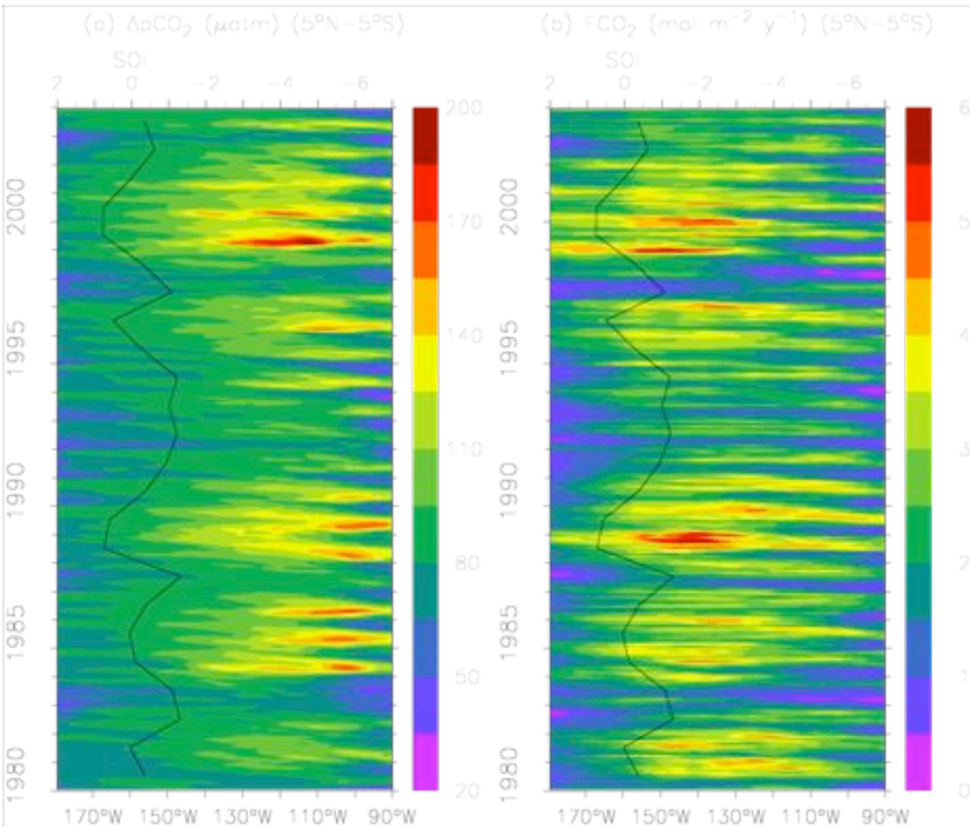
ML biomass, chl. & C:Chl (5ºN-5ºS)
(SOI: white lines)



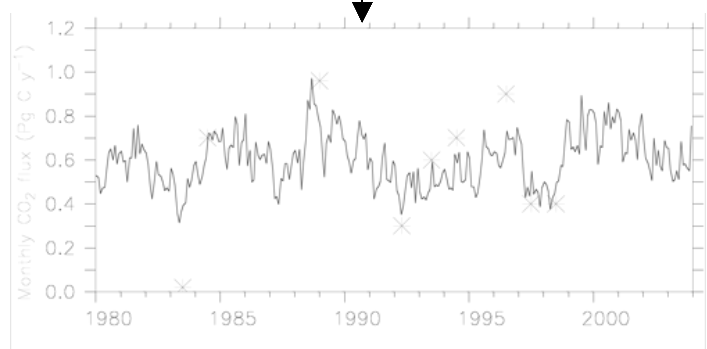
- Chl. ~0.2 in HNLC
- C:Chl: 80-170
- Strong ENSO impact
  - Warm: high C:Chl
  - Cold: low C:Chl

Need more data…

ΔpCO_2 and sea-to-air CO_2 flux



- ΔpCO_2 (50-150)
  - High in EEP
- Outgas 1-5 mol/m^2/y
  - High in CEP
- Strong ENSO impact
- Model vs. data



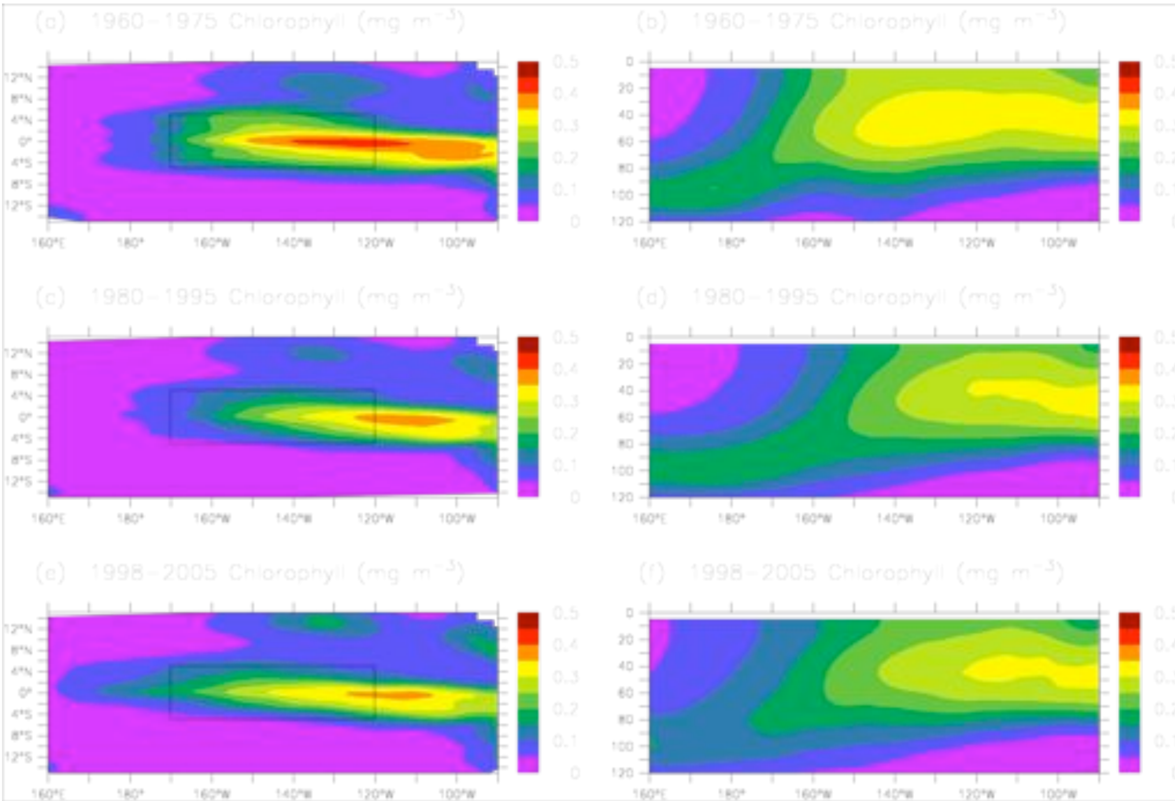
To conclude…

Model can produce ENSO signs in tropical Pacific biogeochemistry.

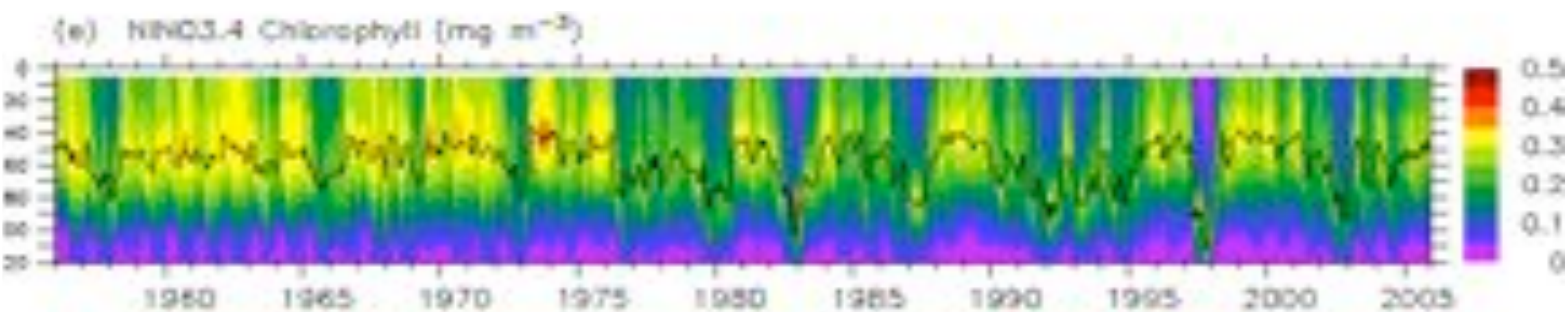
What about PDO…

- 1977 shift?
- 1998 shift?

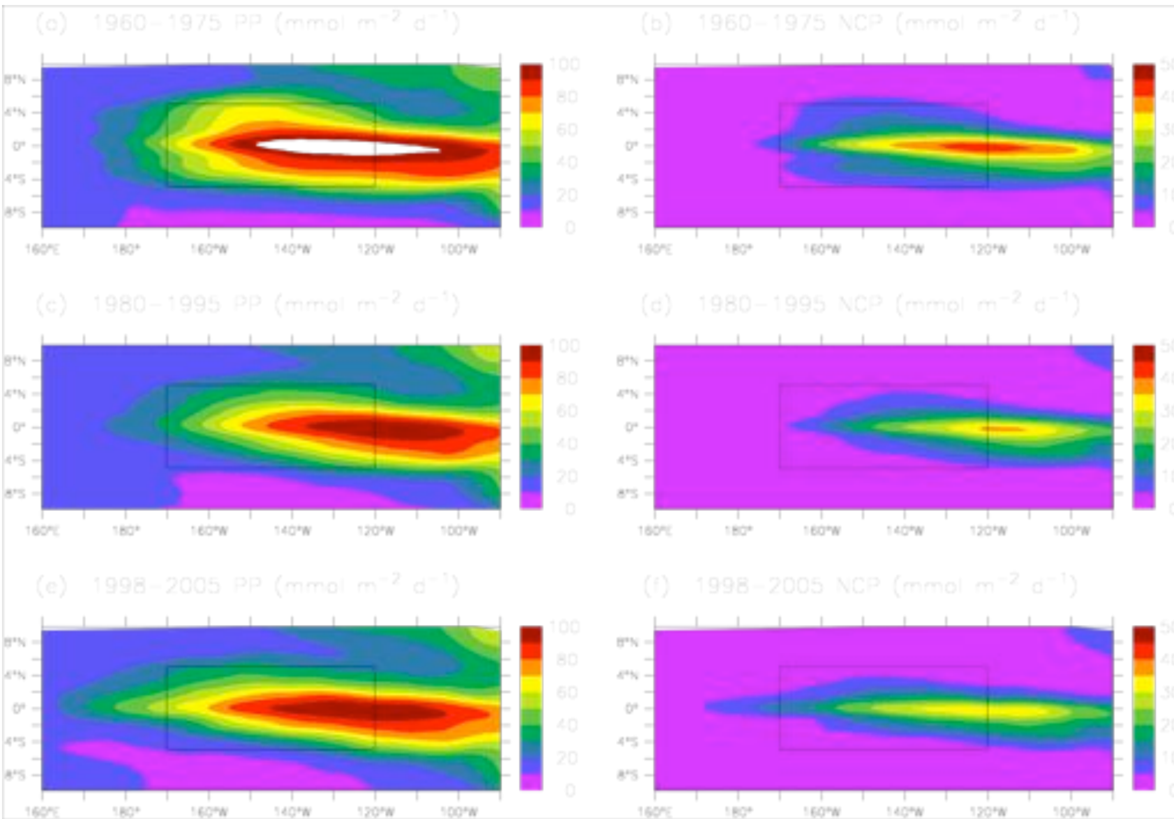
Chl. & DCM



- Spatial distribution
- Vertical variation
- Regime 1 (60-75):
  - Highest surface chl.
  - Shallowest DCM in CEP.

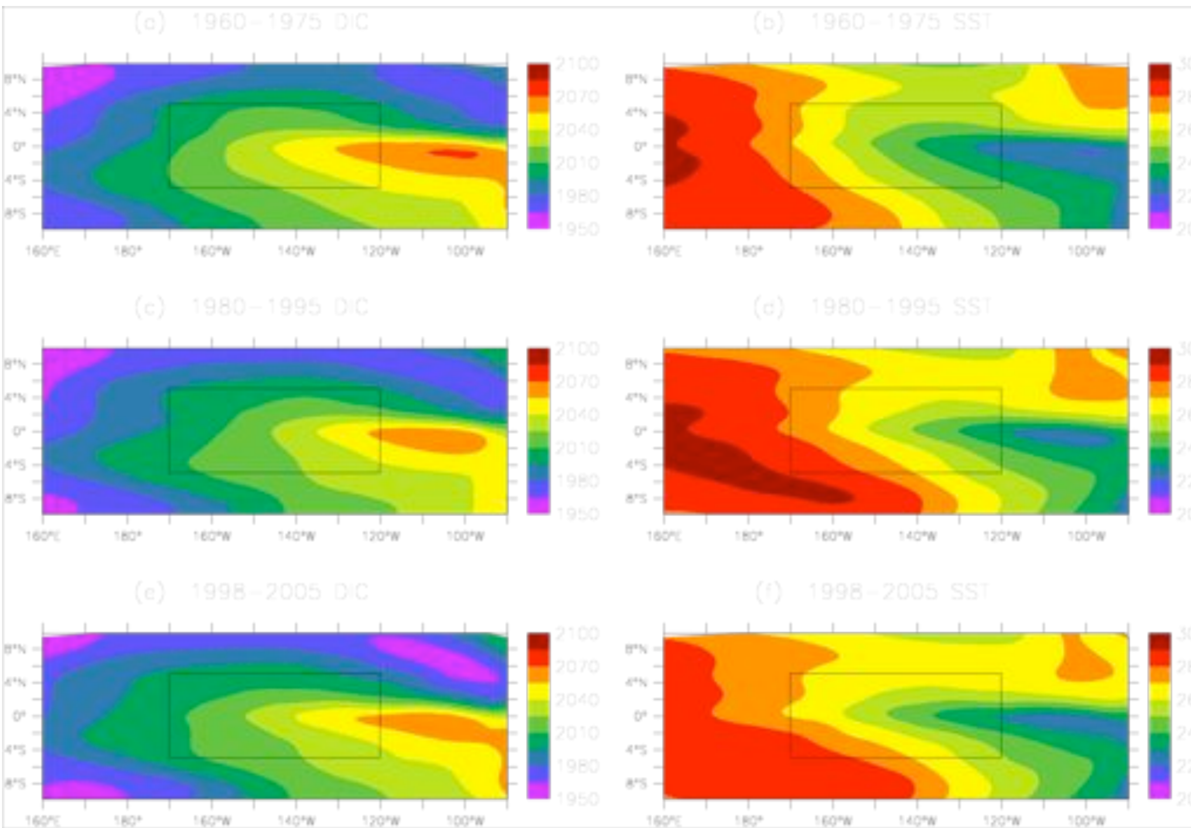


Averaged PP & NCP



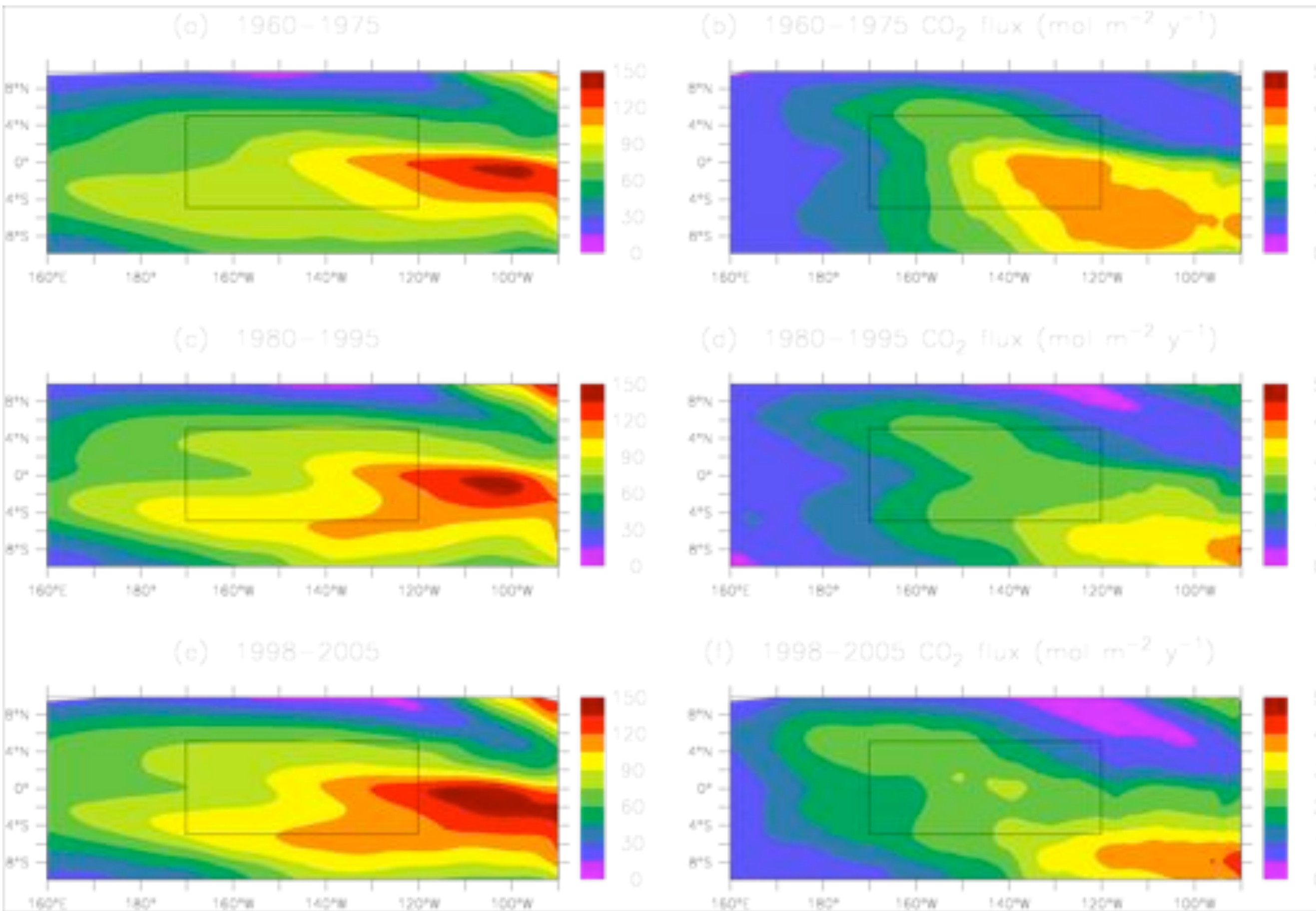
- Spatial variation
- Regime 1:
  - Highest PP & NCP in CEP/EEP
- Regime 3:
  - Highest PP & NCP in WP

Averaged surface DIC & SST



- Spatial pattern
- Regime 1:
  - Coldest SST in CEP/EEP
  - Highest DIC in CEP/EEP
- WP differs: coldest SST & highest DIC in regime 3.

Averaged ΔpCO2 & outgassing (preliminary results)



Statistical analyses (ANOVA and LSD) in the NINO3.4 area.

	1960-75	1980-95	1998-05	LSD(P=0.05)
MLD	49.9	40.9	40.8	2.0
Z20	168	134	123	3.6
Z20 (ob)	*(127)*	*128*	*123*	*3.5*
SST	25.3	26.3	25.9	0.27

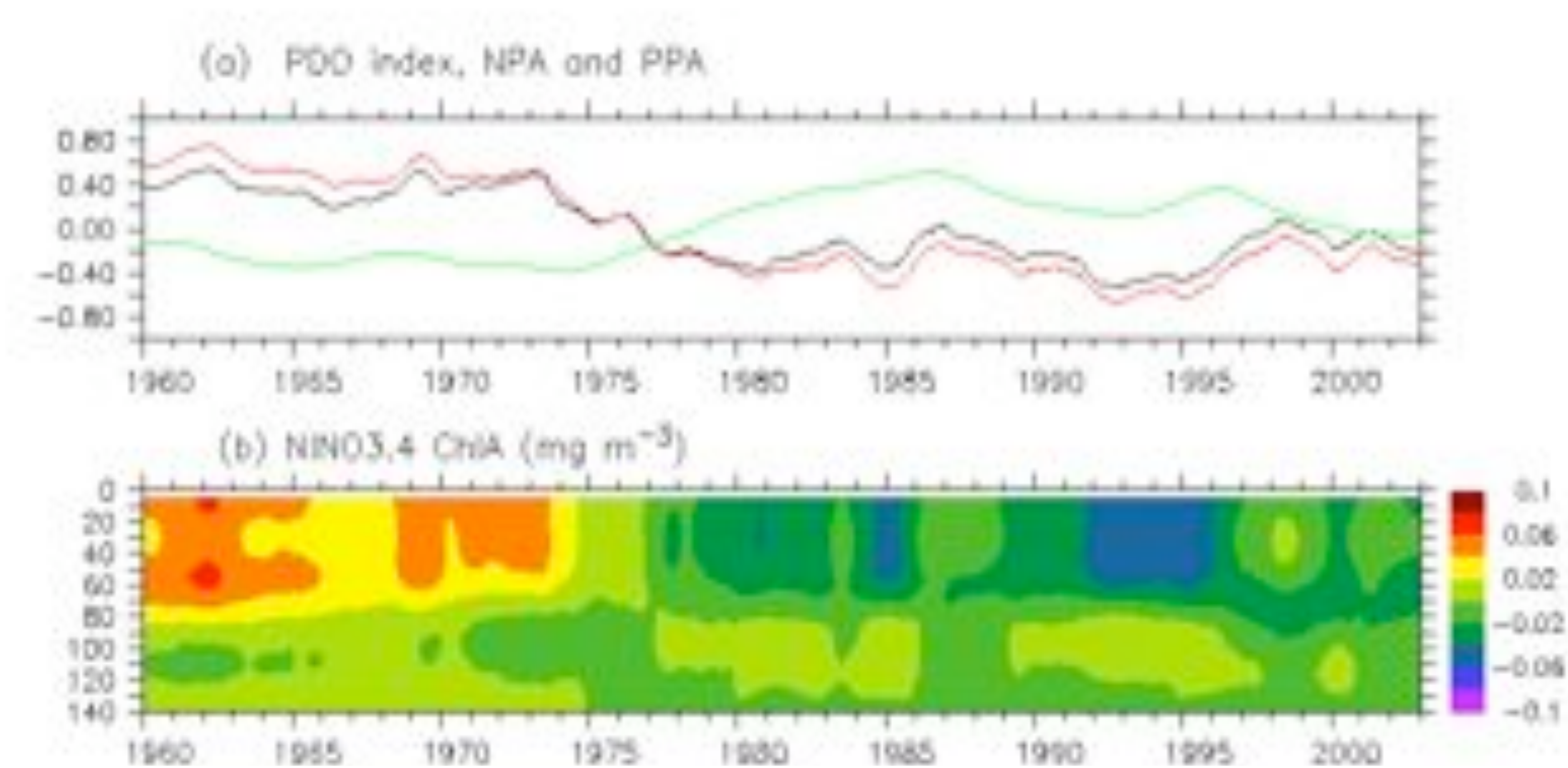
Statistical analyses in the NINO3.4 area (count.)

	60-75	80-95	98-05	LSD
ML Fe	40.5	21.4	25.2	3.8
ML chl.	0.248	0.167	0.185	0.015
DCM	54.8	62.1	55.7	3.4

Statistical analyses in the NINO3.4 area (count.)

	60-75	80-95	98-05	LSD
PP	68.7	50.4	54.7	3.6
NCP	19.3	11.5	13.4	1.6
ΔpCO2	84.3	90.7	94.9	2.5
Outgas.	2.54	2.02	2.13	0.16

6-year running mean



Summary

- ENSO and PDO signs in biogeochemistry
- Two regime shifts
- Regime 3 $\neq$ regime 1
- Biogeochemistry more sensitive than physics?
- Ocean plants stabilize climate