

# Essential Climate Variable:

## Ocean Color Radiometry

Globcour/MedspirationWorkshop  
19-20 Nov. 2008

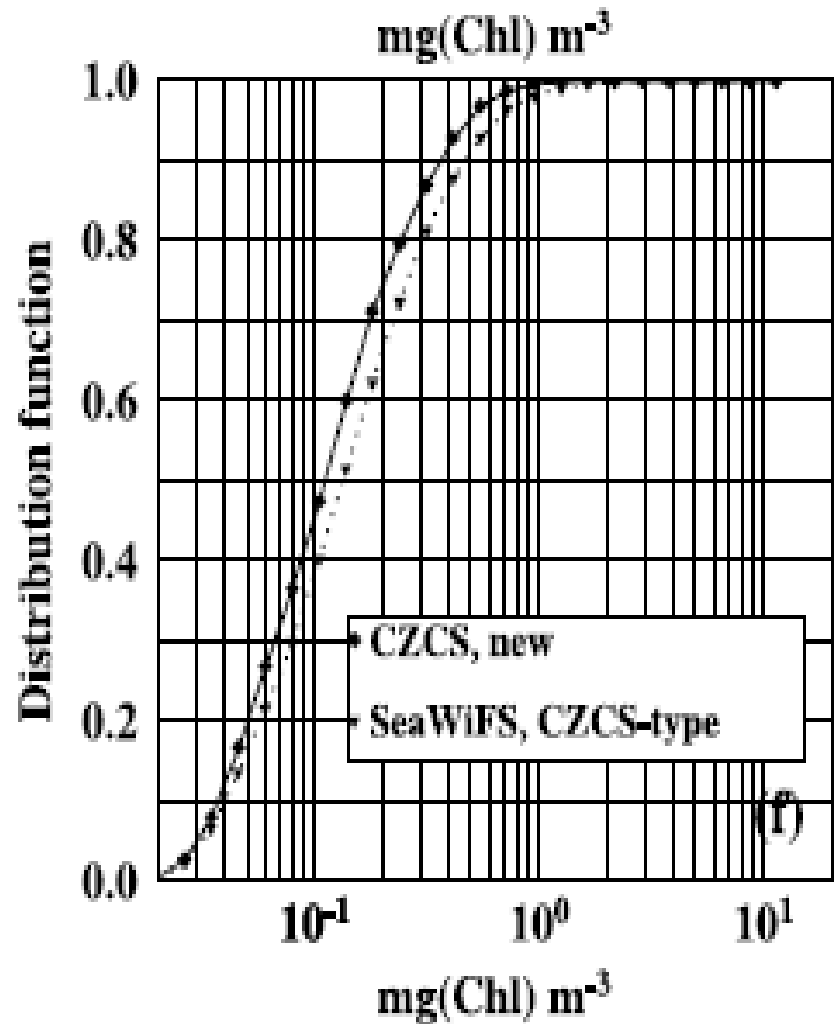
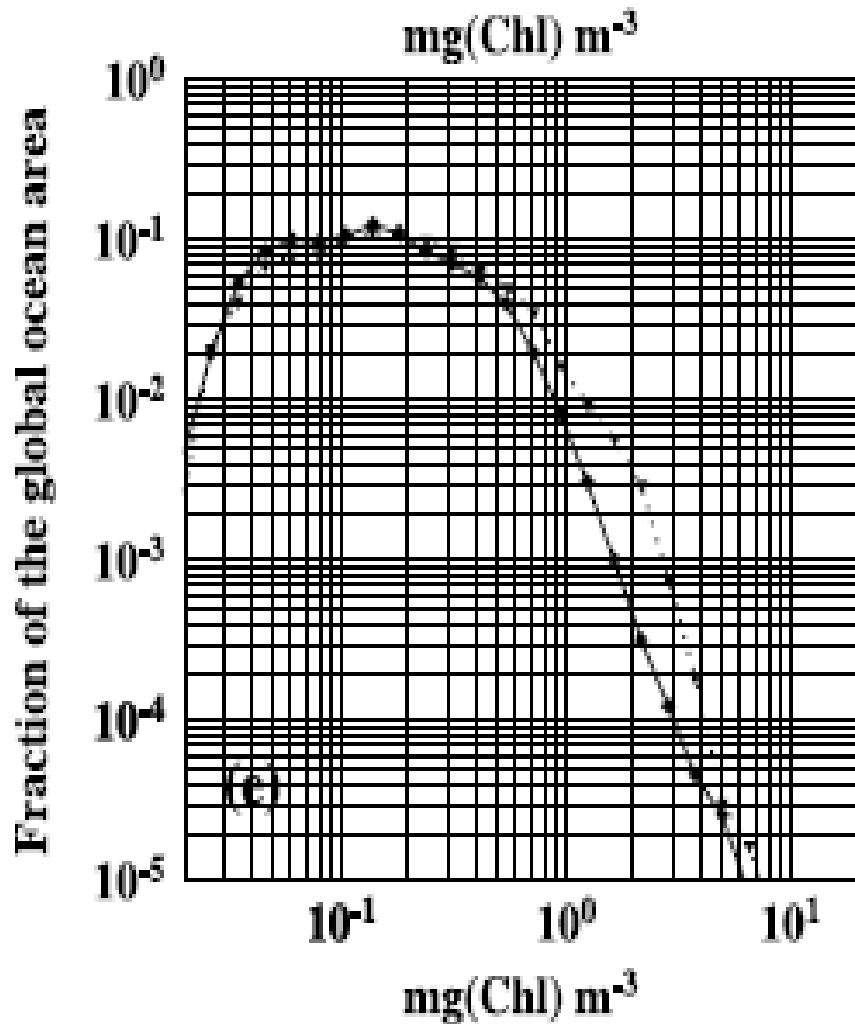
André Morel

# Essential Biogeochemical information provided by OCR, and related to climate and C-cycle:

## Phytoplanktonic biomass at global scale:

- Algal standing stock in terms of [Chl]
  - Derived productivity (C-fixation),  
Control of pCO<sub>2</sub> in upper layer, and air-sea CO<sub>2</sub> exchange
  - C transfer toward the interior of the ocean
  - Upper layer bio-optical properties  
(e.g. heating rate, Mixed layer dynamics, circulation patterns..)
- Compared to open ocean (98%), Coastal zones (2%) have a minor impact on global and climate-related productivity

ANTOINE ET AL.: DECADAL CHANGES IN OCEAN COLOR



Chl distribution in the world ocean

Antoine D, André J-M, Morel A , Global Biogeochem. Cycles, 1995  
 (based on CZCS data)

**Table 2. Division of the Ocean Into Provinces According to Their Annual Mean Levels of Chlorophyll Concentration in the Upper Layer**

| Province     | Chlorophyll<br>mg m <sup>-3</sup> | Area<br>(%) | Production |                       |                                      |
|--------------|-----------------------------------|-------------|------------|-----------------------|--------------------------------------|
|              |                                   |             | %          | Gt C yr <sup>-1</sup> | g C m <sup>-2</sup> yr <sup>-1</sup> |
| Oligotrophic | Chl ≤ 0.1                         | 55.8        | 44.0       | 14.5                  | 91.0                                 |
| Mesotrophic  | 0.1 < Chl ≤ 1                     | 41.8        | 47.5       | 15.7                  | 131.5                                |
| Eutrophic    | Chl > 1                           | 2.4         | 8.5        | 2.8                   | 422.0                                |
| Total        |                                   | 100         | 100        | 33.0                  |                                      |

Only the 50°S to 50°N zonal belt is considered here, thus the total area actually represents 81% of the entire ocean and the total production represents 91% of the production of the entire ocean (line 1 in Table 1).

# Climate evolution of global algal biomass

from the « CZCS era » (1979-1983)

To the « SeaWiFS era » (1998-onward)

- Gregg & Conkright GRL, 2002) :

**A decrease in global chlorophyll by 6%**

- Antoine, Morel, Gordon, Banzon, Ewans (JGR, 2005):

**An increase in global chlorophyll by 22%**

**Note: this study includes a re-processing of the CZCS data**

**And**

**the use of CZCS-type algorithm for SeaWiFS data processing**

# Recent global Chl evolution

Gregg, Casey, McClain (GRL, 2005)

**Mean Chl declined as the mean SST increased within the subtropical gyres (over 6 years)**

Behrenfeld (+ 9 co-authors, Nature, 2006)

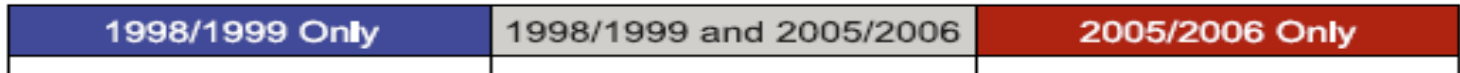
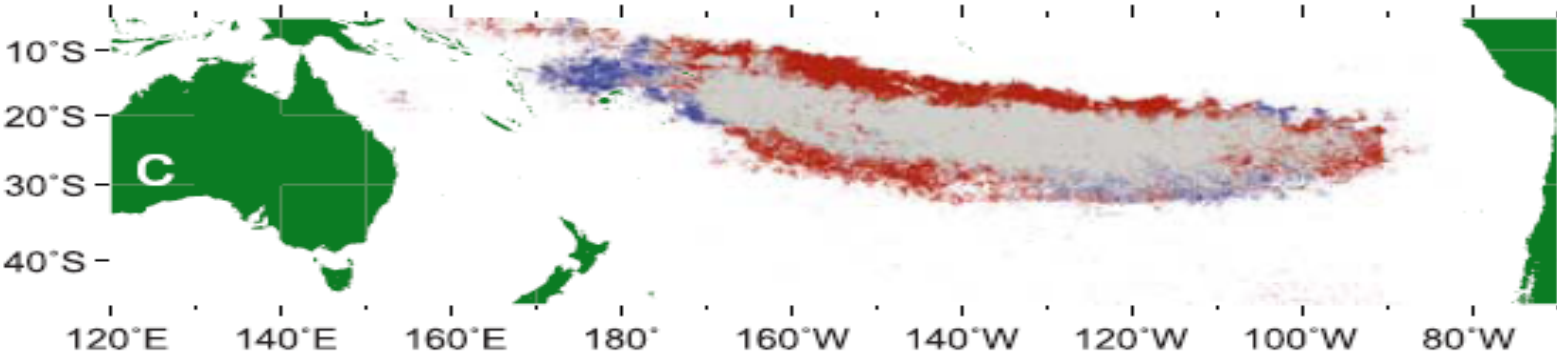
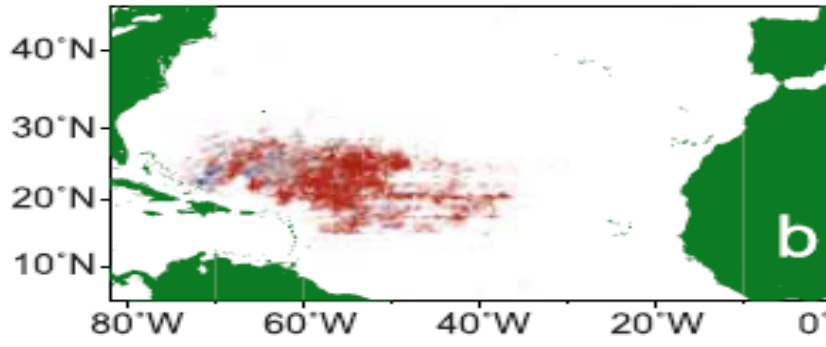
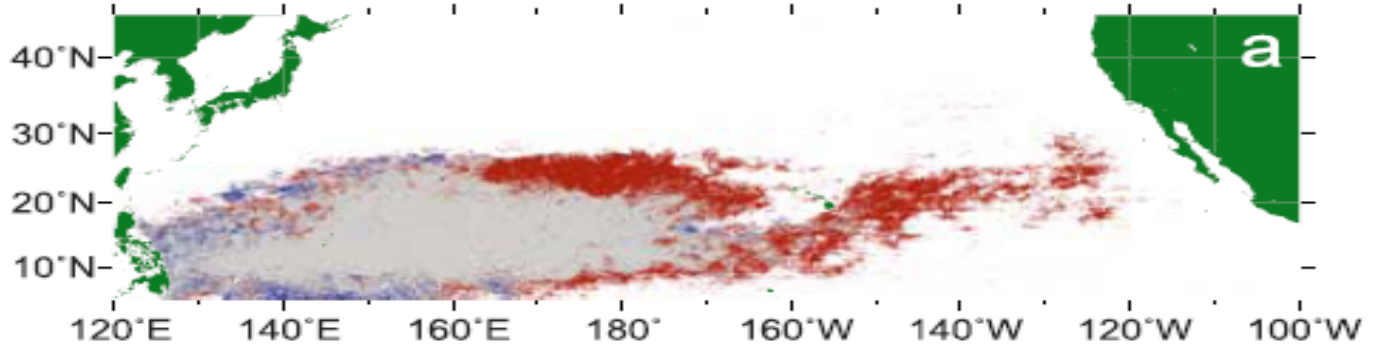
**Phytoplankton biomass and productivity decrease during the recent post-1999 warming**

Polovina, Howell & Abecassis (GRL, 2008)

**Expansion of oligotrophic sub-tropical gyres by 15% over the last 8 years**

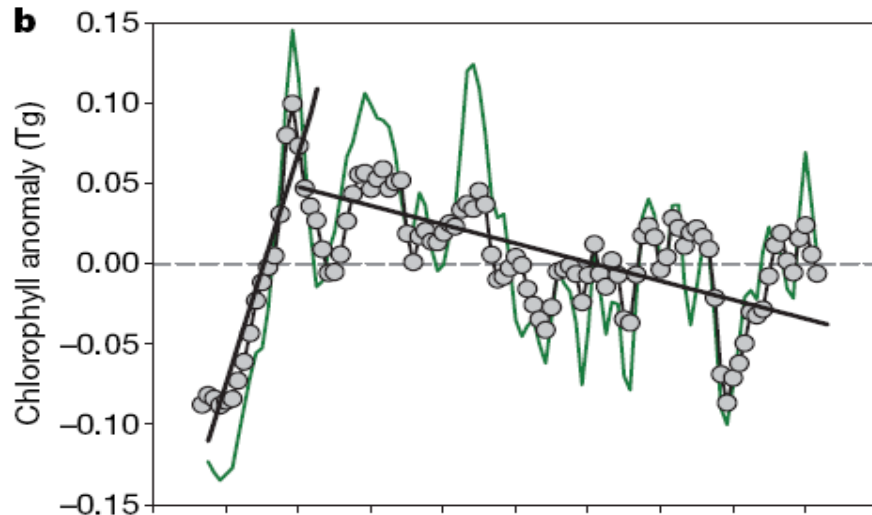
« Oligotrophic gyres »

↓  
defined by  
[Chl] < 0.07  
mg/m<sup>3</sup>



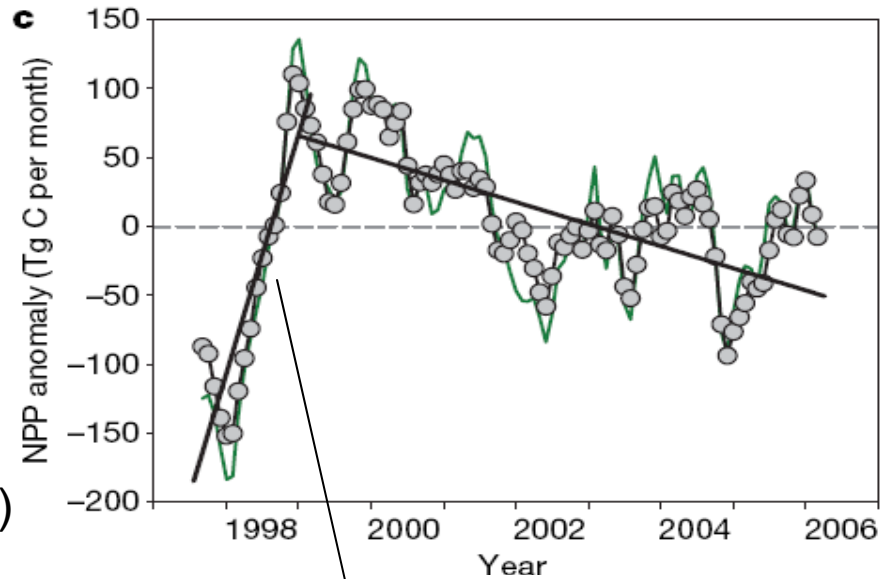
Chlorophyll « anomalies »  
within the permanently  
stratified ocean  
(SST > 15°C)

Monthly means of SST  
grey circles and black lines



NPP « anomalies »

(based on SeaWiFS/AVHRR data)



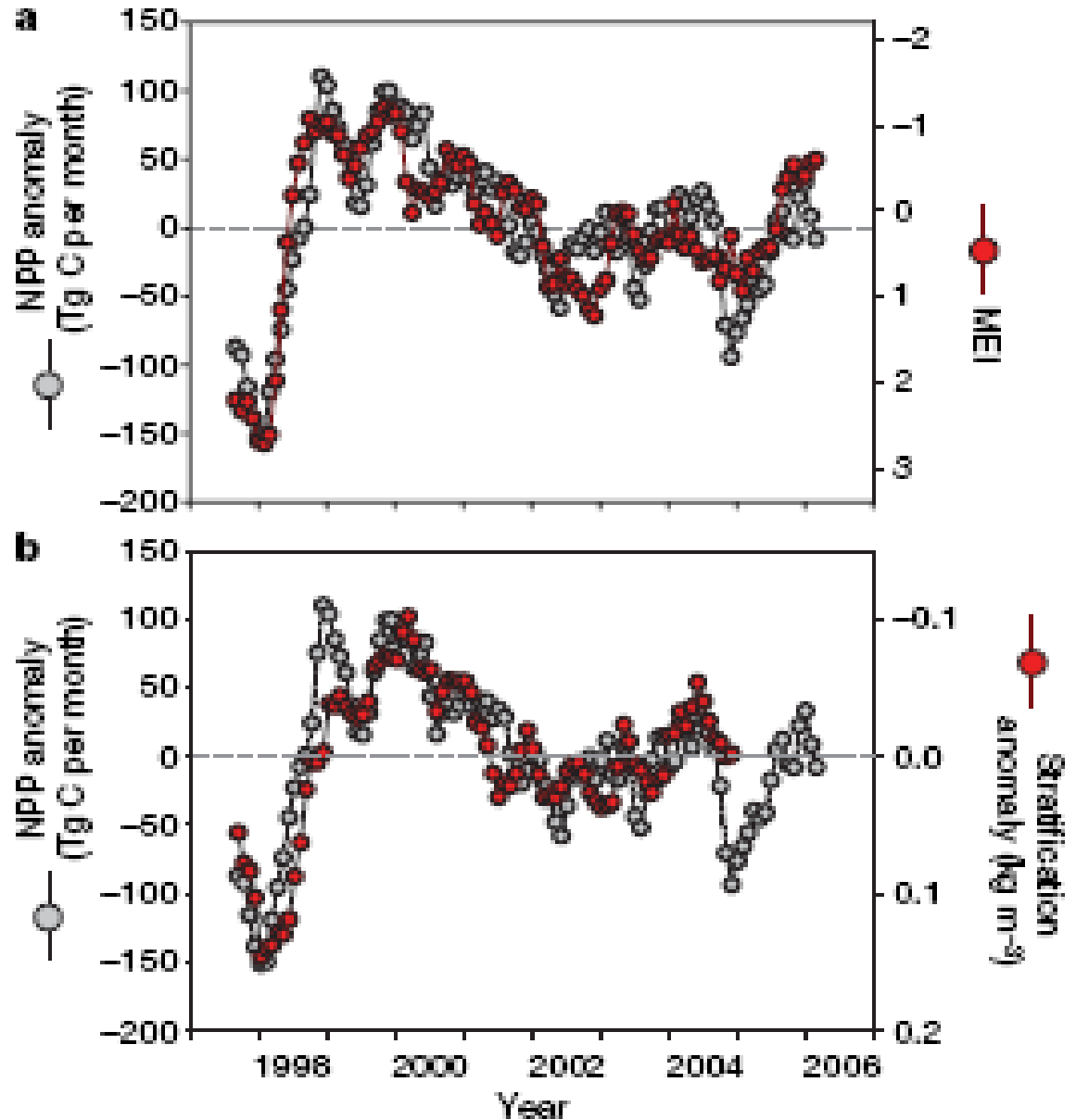
El niño – la niña transition

Multivariate Enso (El Niño Southern Oscillation) Index (MEI)

MEI decreases  
(post 1999)

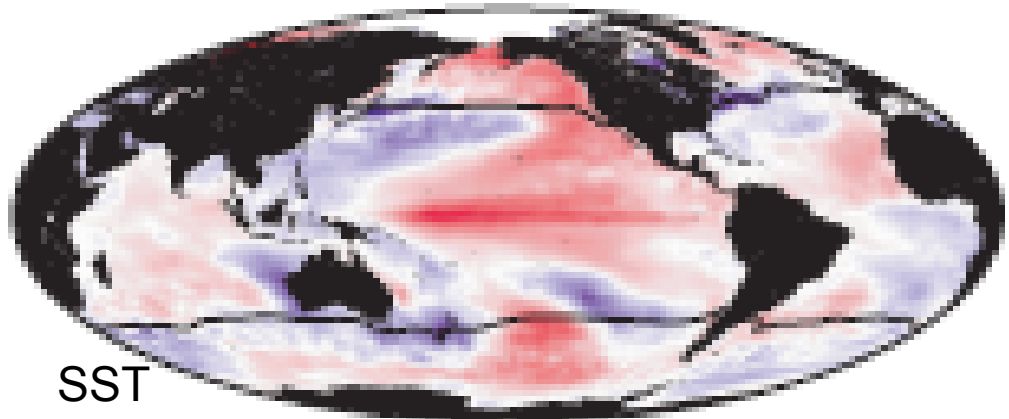
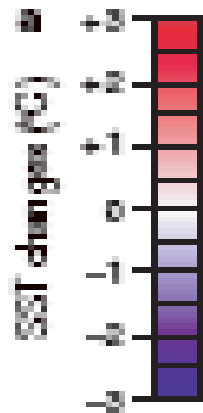
Stratification index  
Increases

↓  
Vertical flux of  
Nutrient decrease,  
NPP decrease.

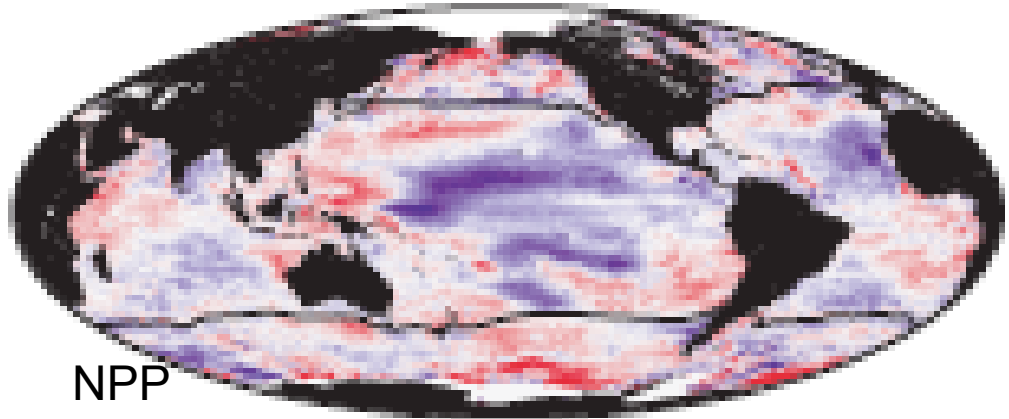
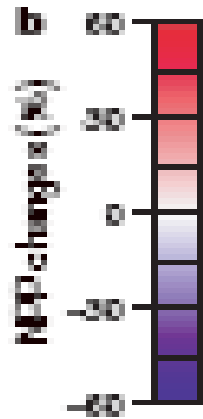


Behrenfeld et al., (Nature, 2006)

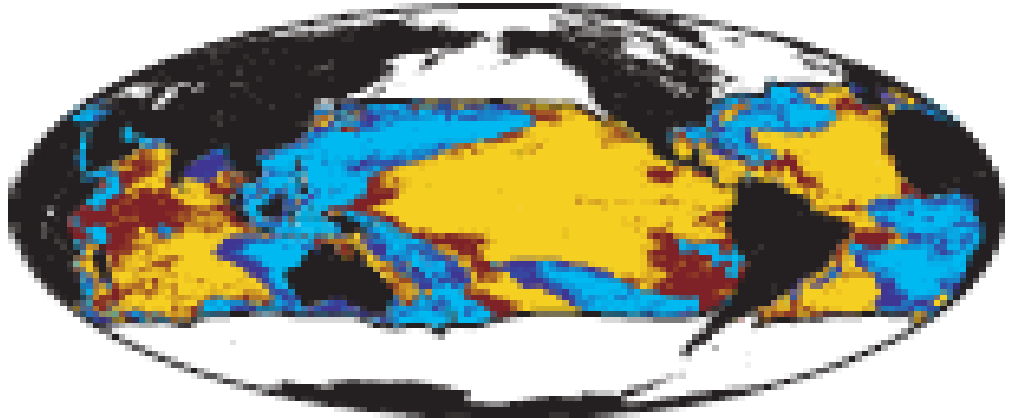
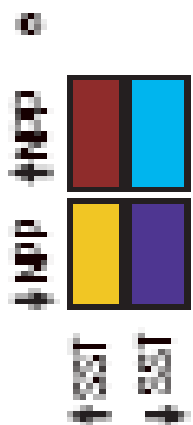
Global change  
(1999 to 2004)  
warming period



SST



NPP



## Behrenfeld et al.'s conclusions:

« .. Changes in upper ocean temperature and stratification influence the availability of nutrients for phytoplankton growth.. » .... ok

« .. Observed reductions in ocean productivity during the recent Post-1999 warming period provide insight on how future climate change can alter marine food web. »  
.....?

but...

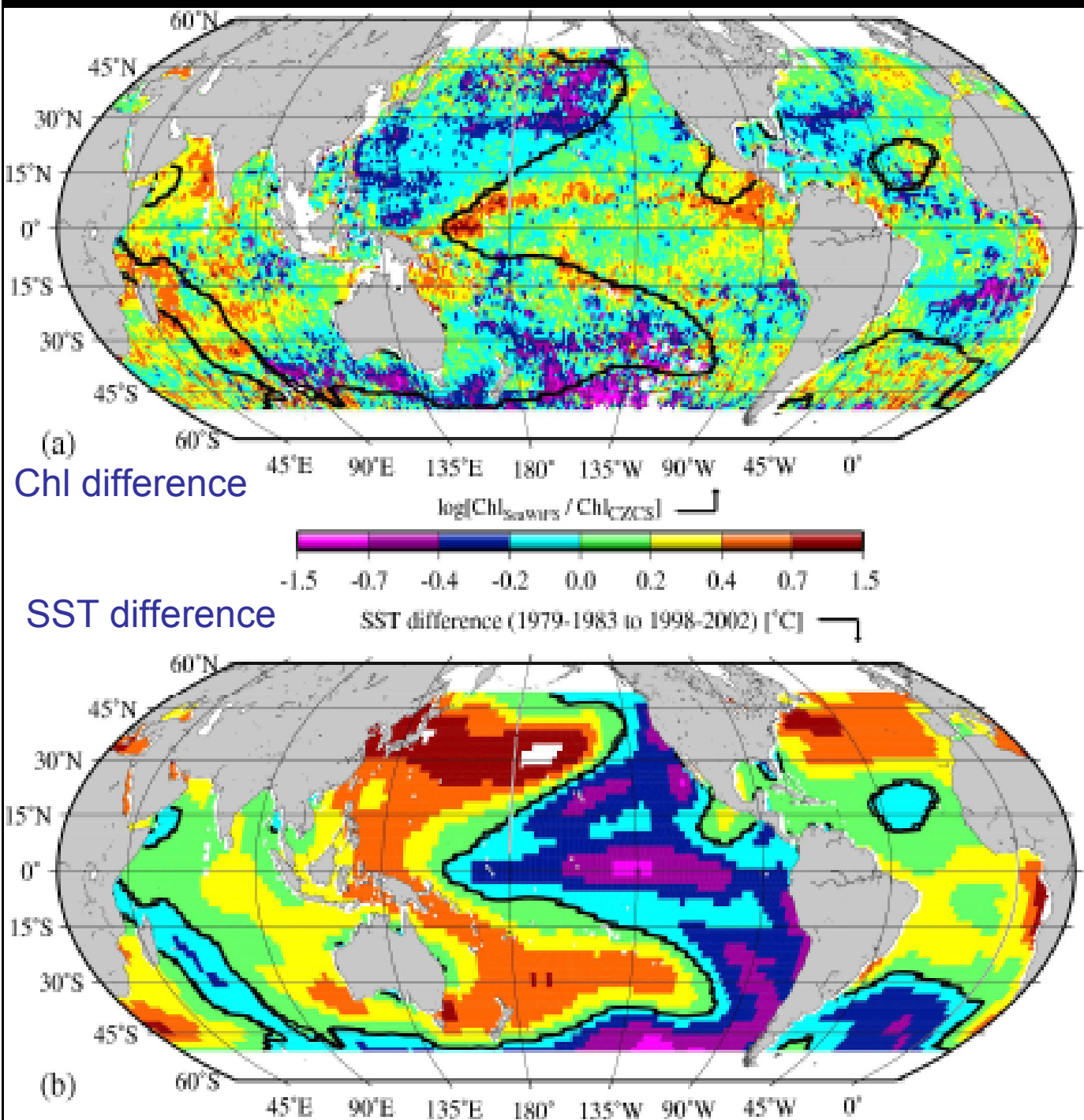
Effect of warming or Something else...?

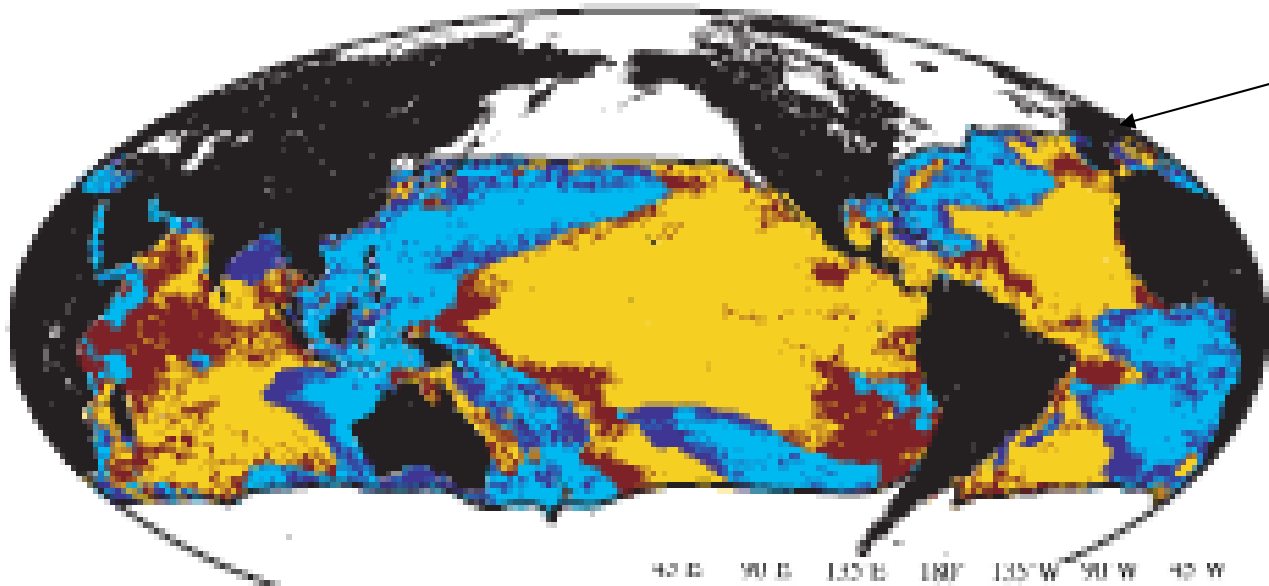
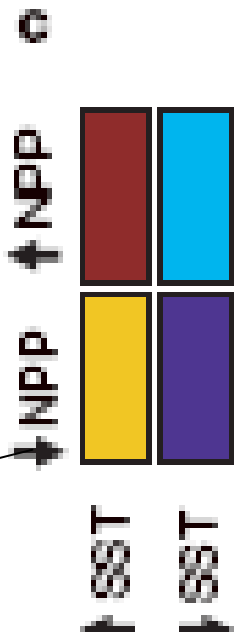
E. Martinez  
D. Antoine  
F. d'Ortenzio  
Ocean Optics XIX  
(Oct.2008)

## Chl and SST change

from  
the CZCS era  
(1979-1983)  
to the  
SeaWiFS era  
(1998-2002)

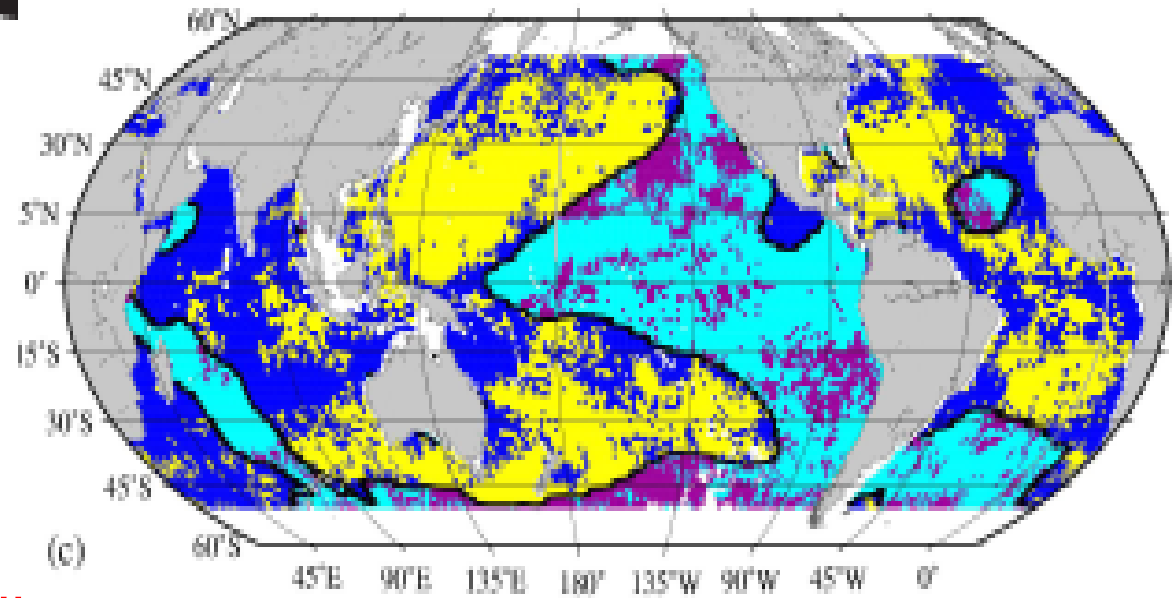
**Black line:**  
0 change in SST



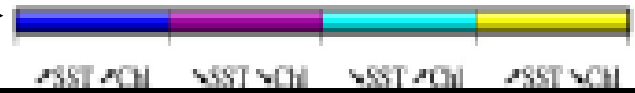


1999 -2004  
(Behrenfeld et al.)

1979 -1983  
Compared to  
1998-2002  
(Martinez et al.)



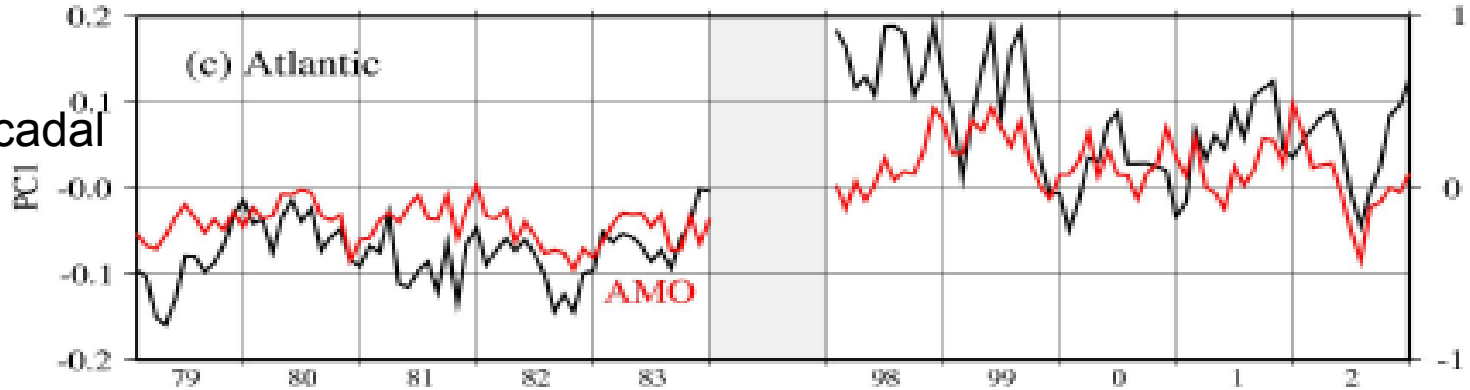
Same color encoding



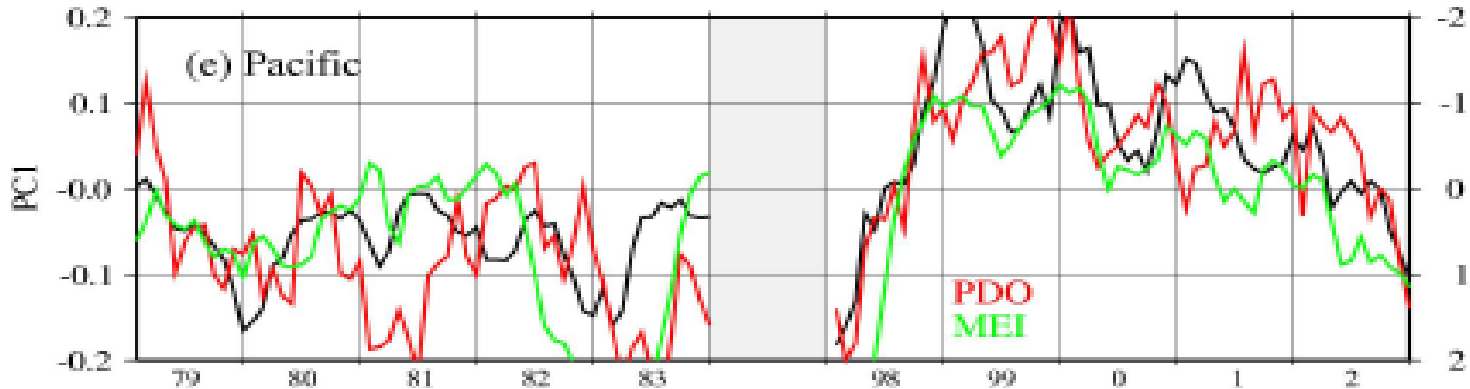
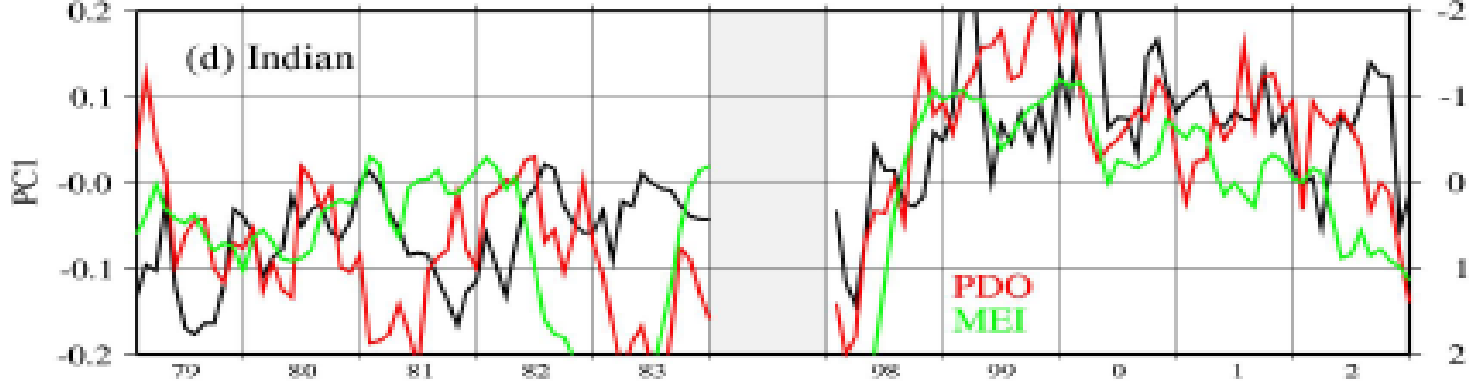
# Chi-SST Multivariate Empirical Orthogonal Functions

Common Principal Components (PC-1 in Black) (Martinez et al., 2008)

Atlantic Multidecadal  
Oscillation  
AMO



Pacific Decadal  
Oscillation  
PDO  
&  
Multivariate Enso  
Index  
MEI



## First Conclusion:

When considering a 27 years (including a 13-y gap !) period...

The changes in Chlorophyll content in the three oceanic basins appear to follow the multi-decadal natural physical oscillations (AMO, MEI..)

(not only a temporary warming episode)

Underlying reason: vertical displacement of the permanent deep thermocline associated with decadal oscillations  
(not the seasonal thermocline)

Possible to show such a (multi-decadal) relationship thanks to the coherently reprocessed CZCS to SeaWiFS archives and thus bridging OC observations over 3 decades.

# Second and general Conclusion:

Beside a re-analyse of historical data,

## **DEFINITELY A NEED**

for ensuring **a permanent climate-quality satellite OC coverage**, able to encompass next decades with similar (or improved) capabilities

**essential, main biogeochemical, climate variable:**  
**LOCAL [Chl] at GLOBAL SCALE**

- As an index of possible climatic changes (Chl patterns) (superimposed to natural oscillations),
- As a descriptor of general circulation and upper layer changes,
- As a key-element of ecosystem-dynamical modelling,
- As a key-component of biogeochemical-physical models, either for validation of, or for assimilation into, models,
- As a crucial parameter (with CDOM) of the oceanic C cycle.

A bunch of other applications, beside the description of the ChI field .....

However, (somewhat ironically)

CHL

Again ChI

Always ChI