CARIACO

CARBON RETENTION IN A COLORED OCEAN

Changes in community structure and productivity in a coastal upwelling system: The CARIACO ocean time-series and implications for future satellite measurements

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Institute for Marine Remote Sensing

Acknowledgements

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  - *Robert Weisberg (USF)*
  - *Kent Fanning (USF)*
  - *Laura Lorenzoni*
  - *[AND MANY OTHERS]*
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  - *NSF*
  - *FONACIT*

  - *FLASA*
  - *USB*
  - *UCV*
  - *UDO*

Location

Cariaco Basin

Southeastern Caribbean

Time series station:
LAT 10.5° N
LON 64.65° W

~1400 m

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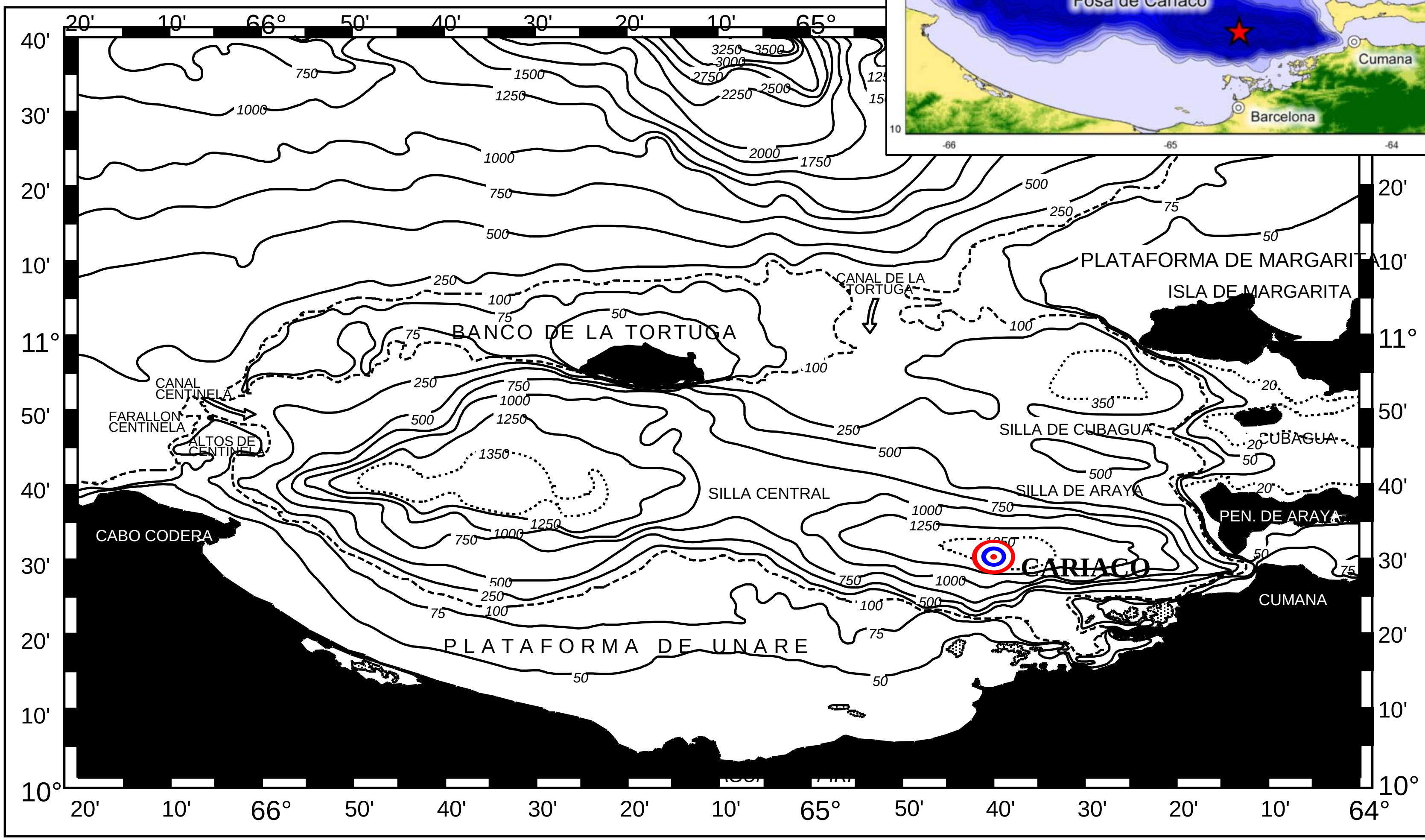
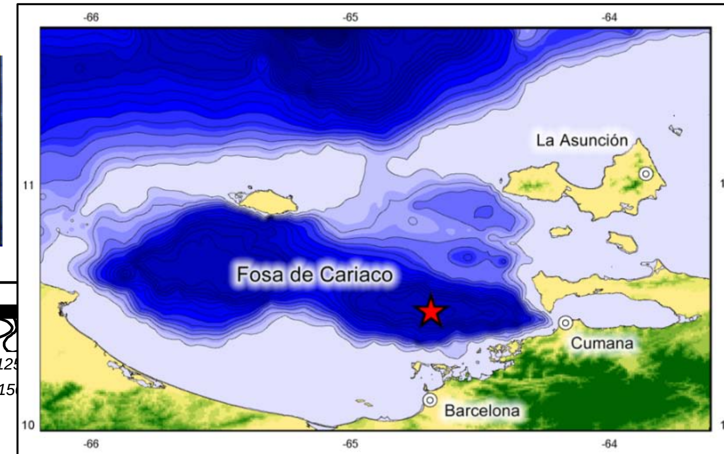


CANAL CENTINELA
FARALLON CENTINELA
ALTOS DE CENTINELA
BANCO DE LA TORTUGA
CANAL DE LA TORTUGA
PLATAFORMA DE MARGARITA
ISLA DE MARGARITA
SILLA DE CUBAGUA
CUBAGUA
SILLA CENTRAL
SILLA DE ARAYA
PEN. DE ARAYA
CABO CODERA
CARIACO
CUMANA
PLATAFORMA DE UNARE
66°
65°
64°
11°
10°



La Asunción
Fosa de Cariaco
Cumana
Barcelona

Cariaco Basin Characteristics

Tropical climate

Basin embedded in the continental shelf.

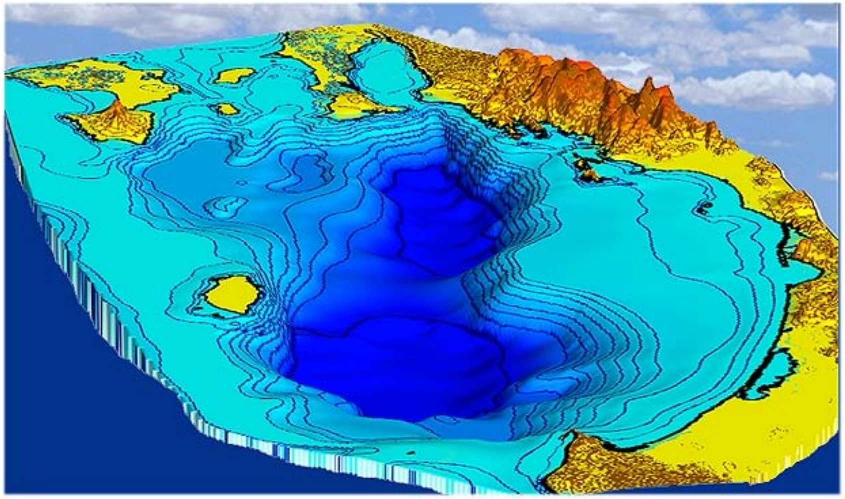
High primary production (~500 gC/m2/y)

Alternating seasonal upwelling and river discharge

Permanent **anoxia** below ~250m: undisturbed sediments.

Local **river inputs** (Minimal Orinoco and Amazon river influence)

High **Secondary production**: Sardine, demersal and other pelagic fisheries (~500Ktm/y).



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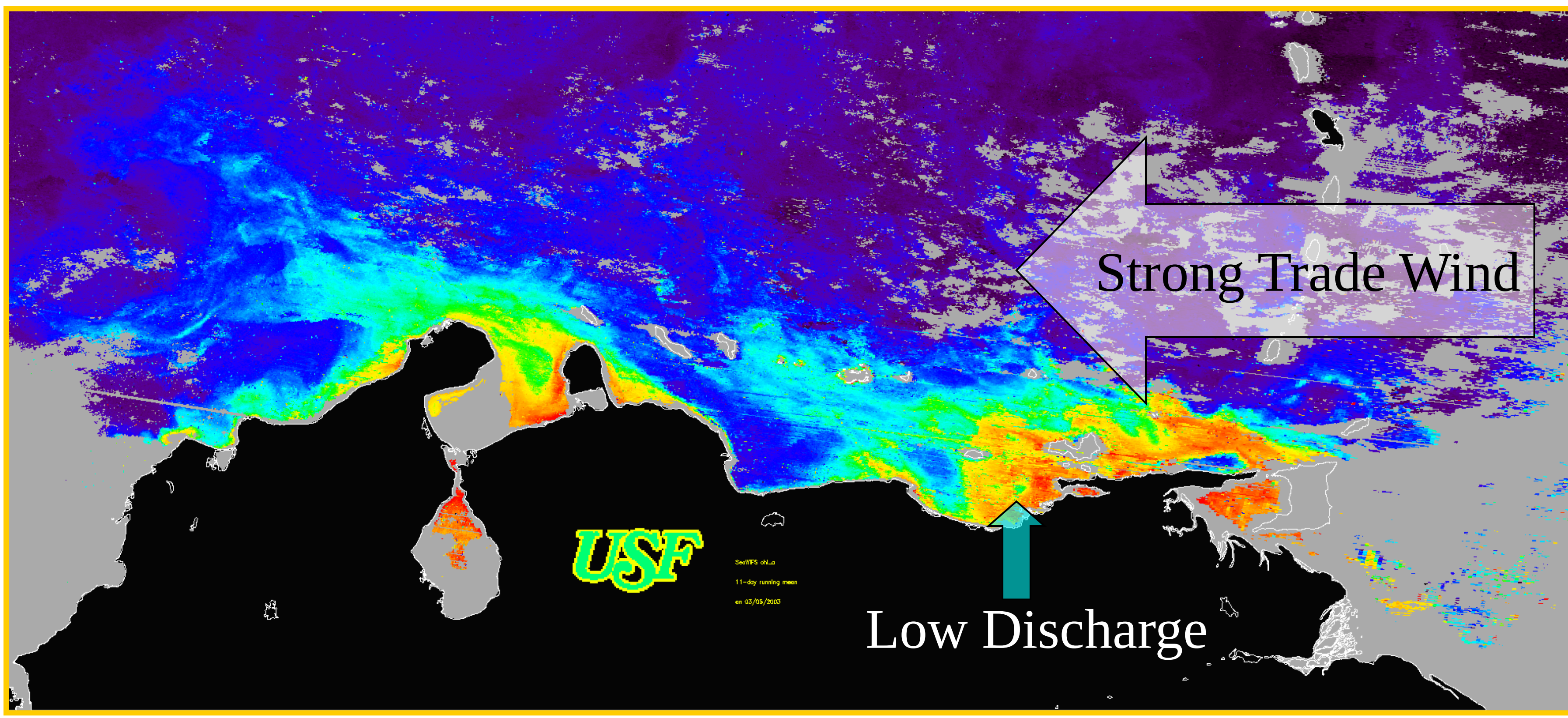
SeaWiFS satellite-derived
Chlorophyll-a and
other “pigments”

Mar 5, ’03

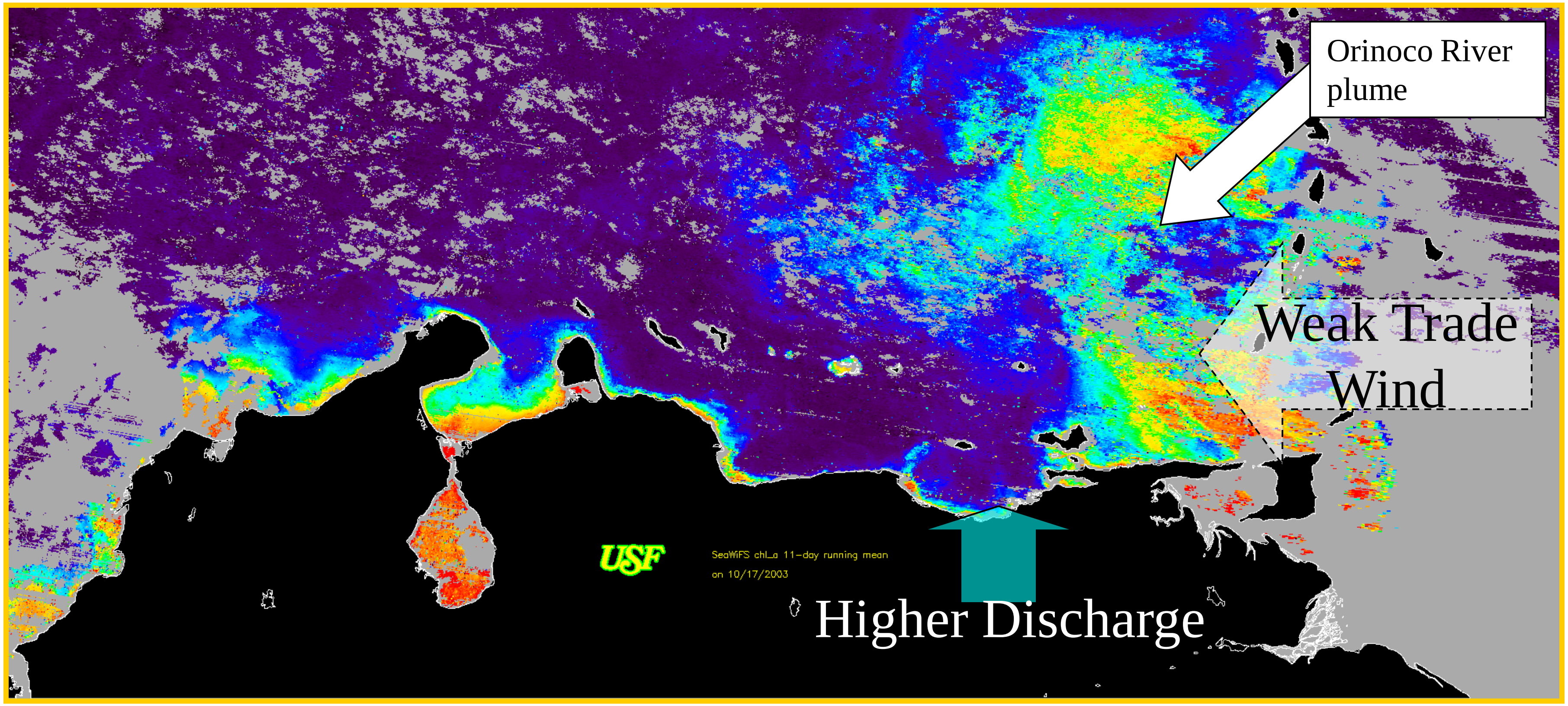
First half of year:
Windy / dry
High coastal upwelling
High primary production
Low river discharge



SeaWiFS satellite-derived Chlorophyll-a and other "pigments"

Oct 17, '03

Second half of year:
Less wind / wet
Low upwelling
Low primary production
High river discharge



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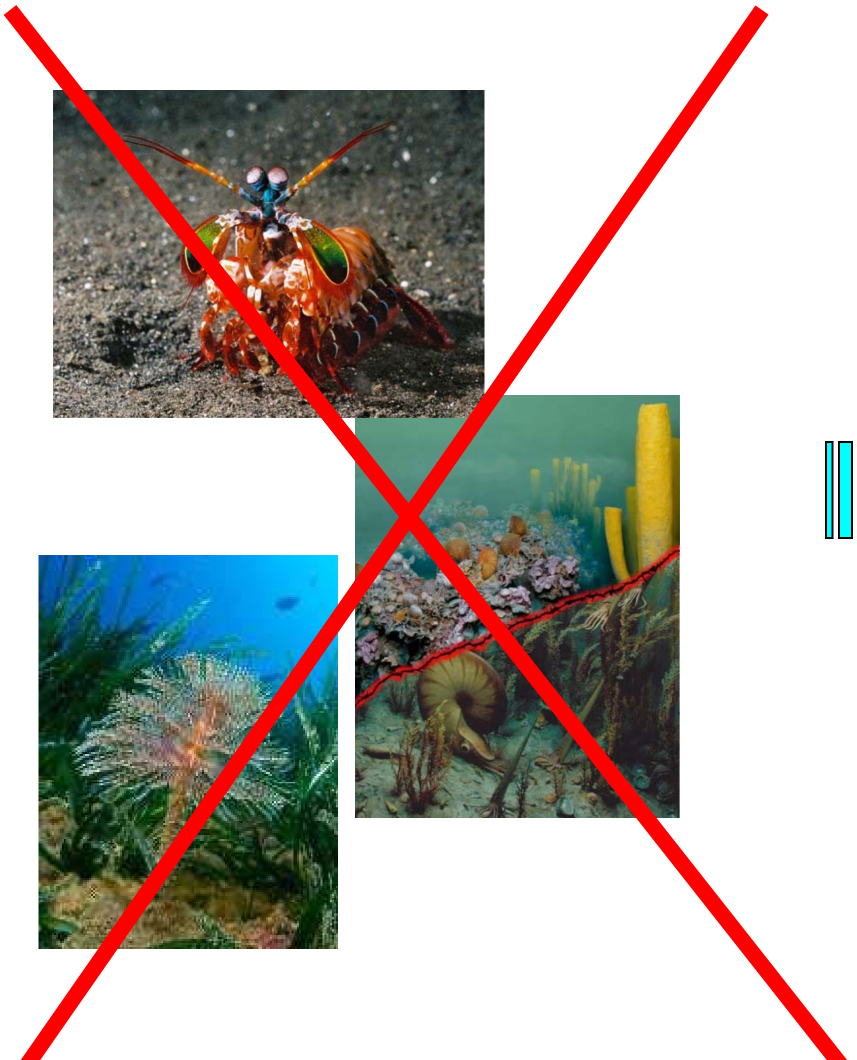
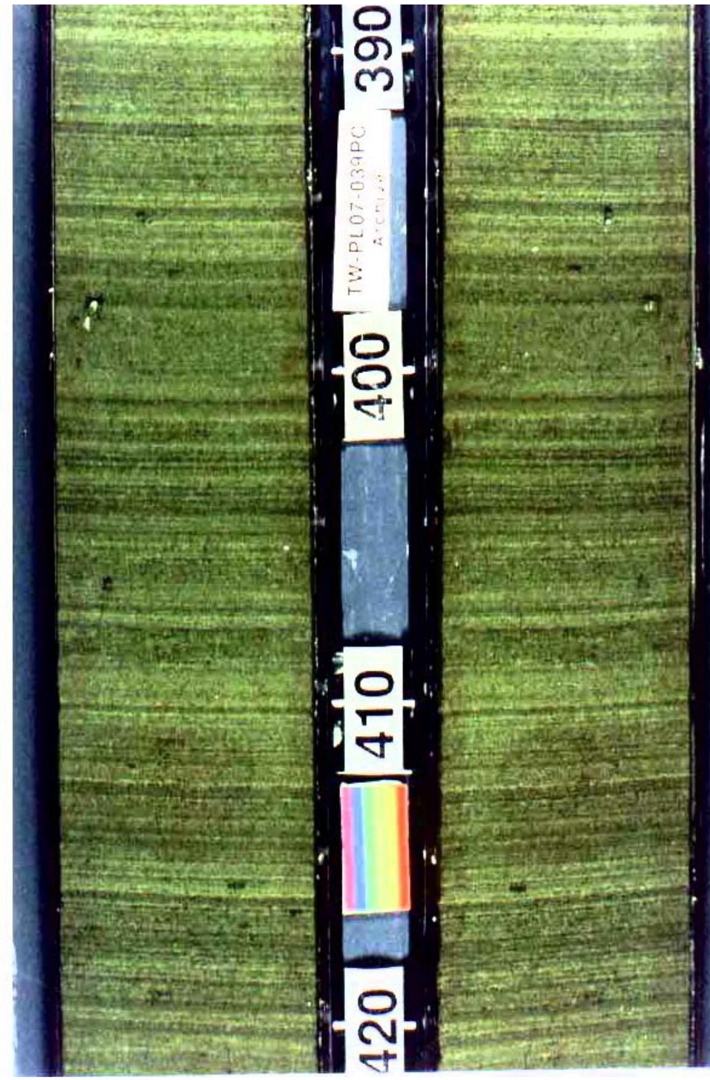
No benthic organisms



Laminated (“varved”) sediments



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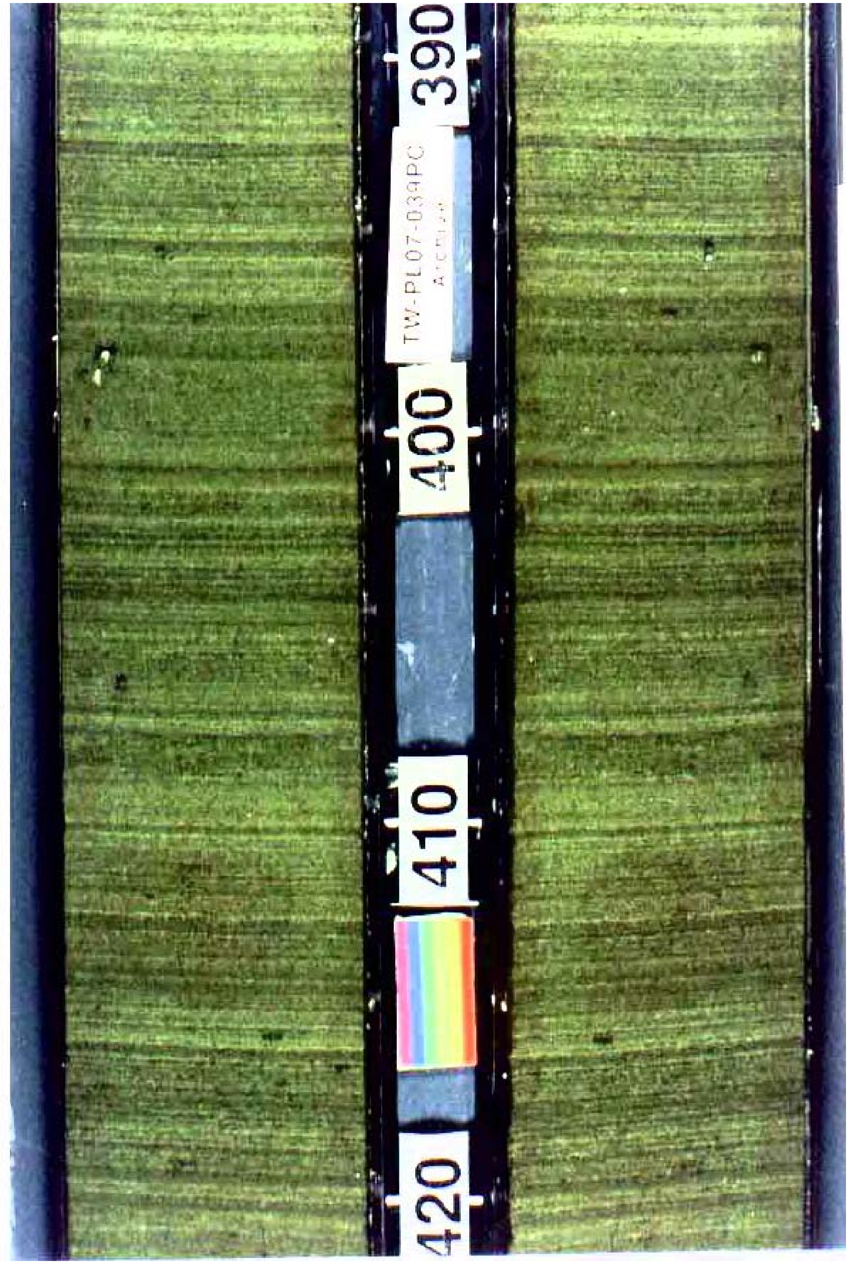
Sediment varves:

- *Lighter color laminae:*
  - *rich in plankton*
  - *(upwelling period)*
- *Dark laminae:*
  - *Riverine*
  - *detrital minerals*
  - *(rainy season)*



ODP Core Site 1002C.
Lea et al., 2003

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Significance of basin

- *Continental margin / upwelling processes*
- *Oxic/anoxic oceanographic processes*
- *Sediment climate record (natural sediment trap)*
    - *anoxic bottom and absence of bioturbation lead to sediment varves*

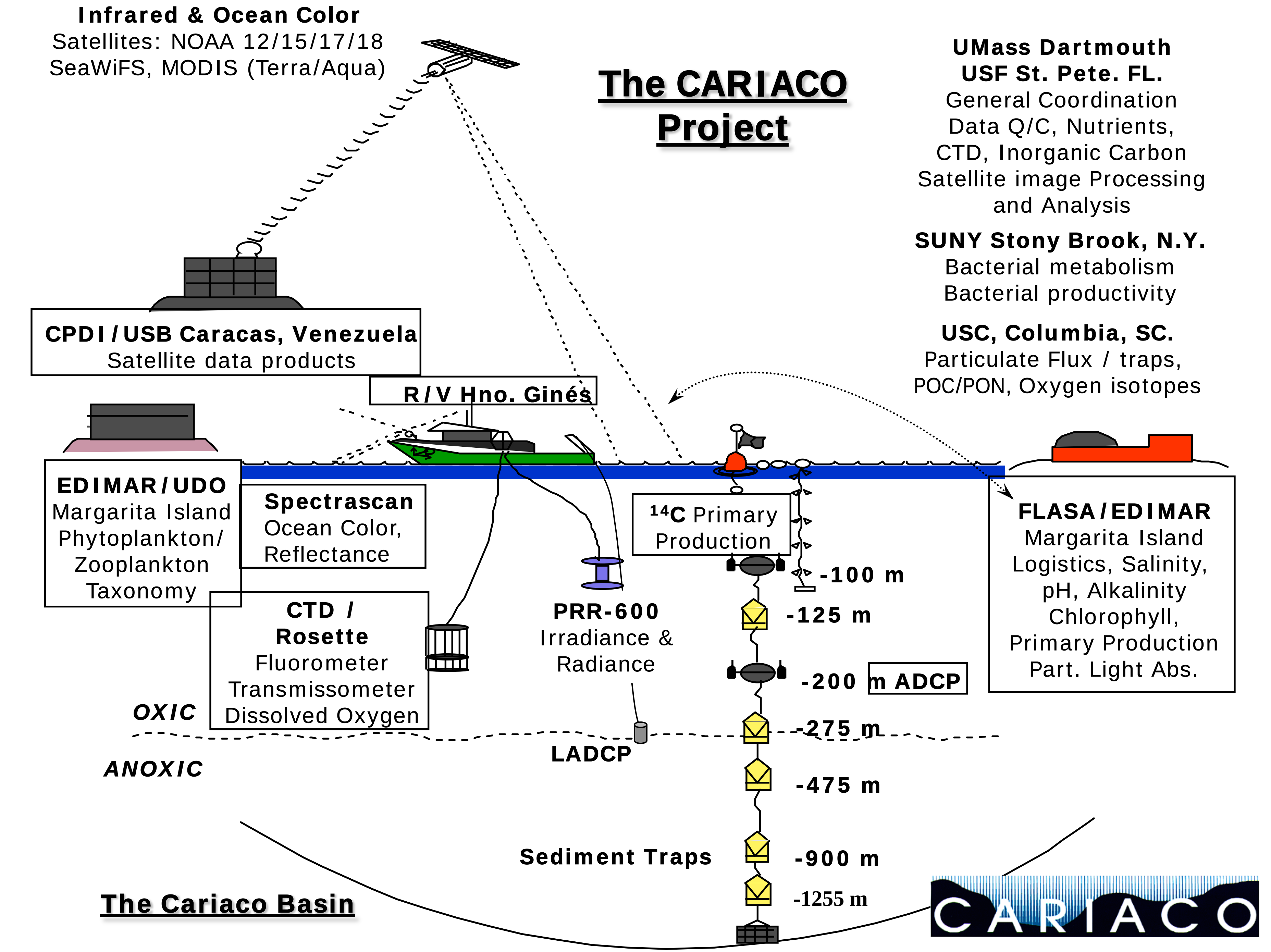
TIME SERIES PROJECT
Scientific Objectives

- *Understand linkages between oceanographic processes and the production and sinking flux of particulate matter in the Cariaco Basin*
- *Explain climate / paleoclimate changes in the region (including Atlantic Ocean)*

Objectives of bio-optical research

Assess fundamental ecological characteristics of the system rapidly, repeatedly, over large scales and long times, and economically (e.g. use of remote sensing). Specifically:

- *Phytoplankton concentration*
- *Primary productivity*
- *Functional groups and community structure*


The CARIACO Project
Infrared & Ocean Color
Satellites: NOAA 12/15/17/18
SeaWiFS, MODIS (Terra/Aqua)
UMass Dartmouth
USF St. Pete. FL.
General Coordination
Data Q/C, Nutrients,
CTD, Inorganic Carbon
Satellite image Processing
and Analysis
SUNY Stony Brook, N.Y.
Bacterial metabolism
Bacterial productivity
USC, Columbia, SC.
Particulate Flux / traps,
POC/PON, Oxygen isotopes
CPDI / USB Caracas, Venezuela
Satellite data products
R/V Hno. Ginés
EDIMAR/UDO
Margarita Island
Phytoplankton/
Zooplankton
Taxonomy
Spectrascan
Ocean Color,
Reflectance
CTD /
Rosette
Fluorometer
Transmissometer
Dissolved Oxygen
PRR-600
Irradiance &
Radiance
14C Primary
Production
-100 m
-125 m
-200 m ADCP
-275 m
-475 m
-900 m
-1255 m
FLASA/EDIMAR
Margarita Island
Logistics, Salinity,
pH, Alkalinity
Chlorophyll,
Primary Production
Part. Light Abs.
OXIC
ANOXIC
LADCP
Sediment Traps
The Cariaco Basin
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CARBON RETENTION IN A COLORED OCEAN

TIME SERIES DETAILS

- 10º30’N, 64º40’W (Venezuela)
- Operation: since November ’95 (monthly cruises, moorings)

  -hydrography / sediment traps

  -bio-optical /biogeochemical::

  * Phytoplankton concentration

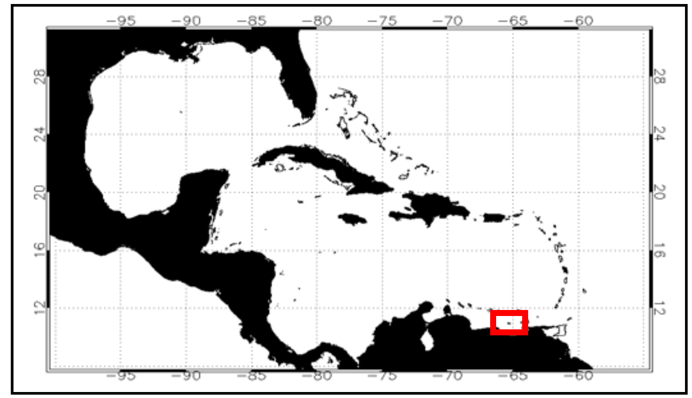
  * HPLC pigment composition

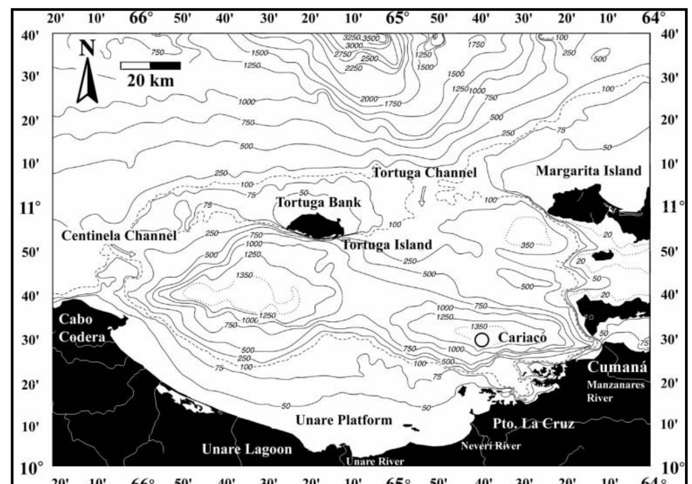
  * Taxonomy

  * Primary productivity

  * Reflectance profiles

  * Hyperspersspectral reflectance





CARIACO

R/V Hermano Gines

25 m (~80 ft)

116 metric Ton

13 crew

8 science party

~$4,000/day

Sampling and keeping records…

Filtering…filtering…24 h a day…

Yrene Astor
Keeps us in line

CTD/rosette hydrography

Sediment traps

Zooplankton

Primary productivity

Bio-optics (ocean color)

CARIACO cruises and data policy

Since Nov 1995:
172 core cruises (August 2010)
29 sediment trap and current meter recovery-redeployment cruises
30 biogeochemical and microbial process cruises
6 regional cruises

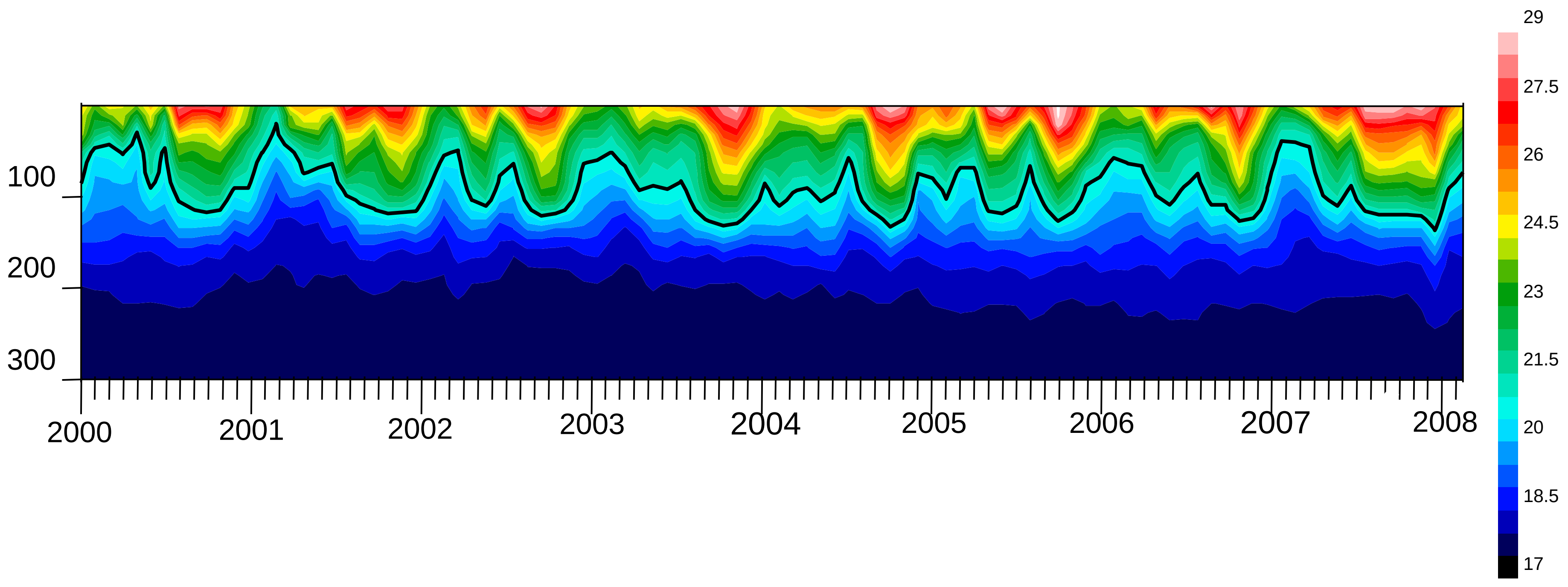
Implemented a policy for open and public sharing of samples, data, and information

http://cariaco.ws (Spanish)

http://www.imars.usf.edu/CAR/ (English)

http://ocb.whoi.edu/jg/dir/OCB/CARIACO/

Temperature



Upwelling intensity has decreased since we started the series

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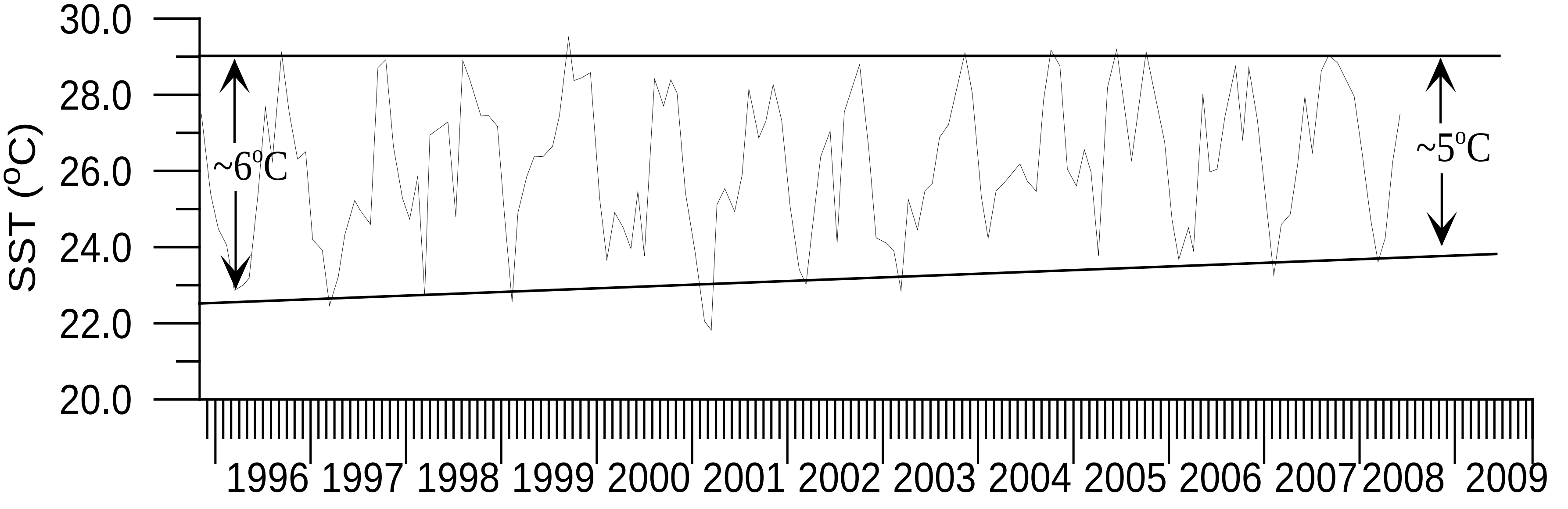
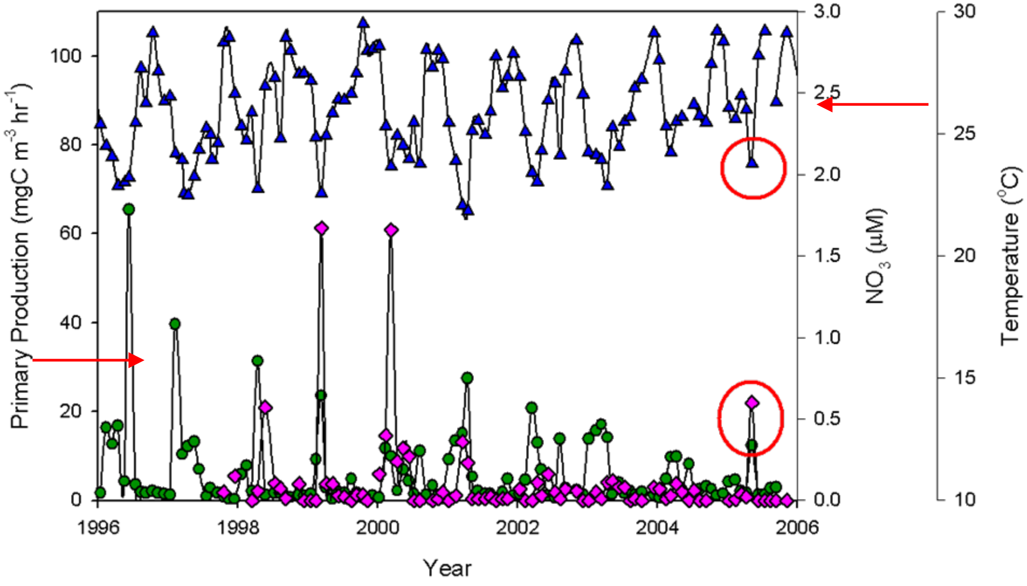
Long Term Changes in SST: Reduction in Annual Range



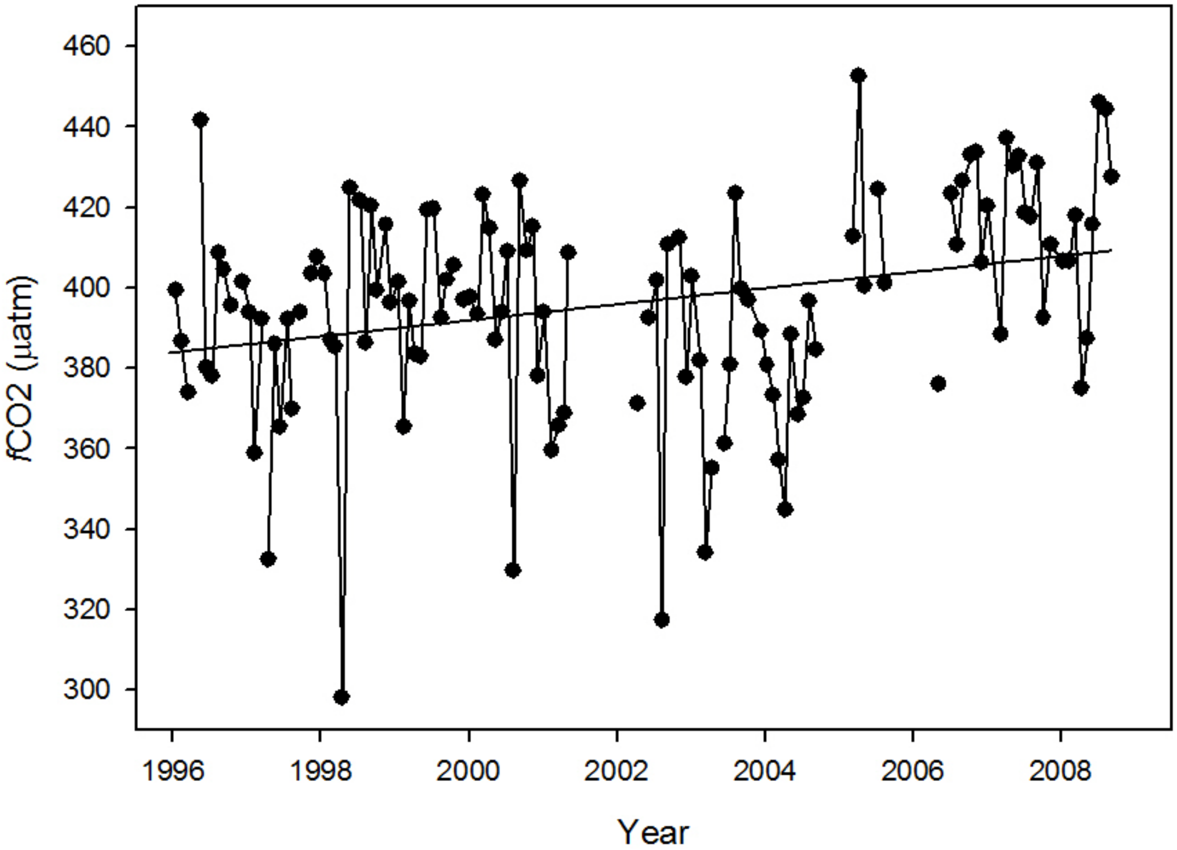
Contributed by
R. Thunell, USC

Primary Production

- *Chlorophyll and primary production highest in Jan-Apr*
- *A secondary peak seen during the summer upwelling*
- *Shift in phytoplankton community since ~2001 (now smaller cells)*
- *Amplitude of PP decreased since ~2000, with broader peaks*
- *Total annual production remains similar (~500 gC/m2/y)*



Trend in CO2 fugacity: fCO2 Increasing?



	Temperature	Δ	Salinity	Δ	fCO2	Δ
Max 1996-2001	29.50	**7.68**	37.00	**0.92**	441.70	**143.40**
min 1996-2001	21.82		36.07		298.30	
max 2002-2009	30.00	**7.15**	37.06	**1.22**	452.60	**135.30**
min 2002-2009	22.85		35.84		317.30	

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Sediment trap samples

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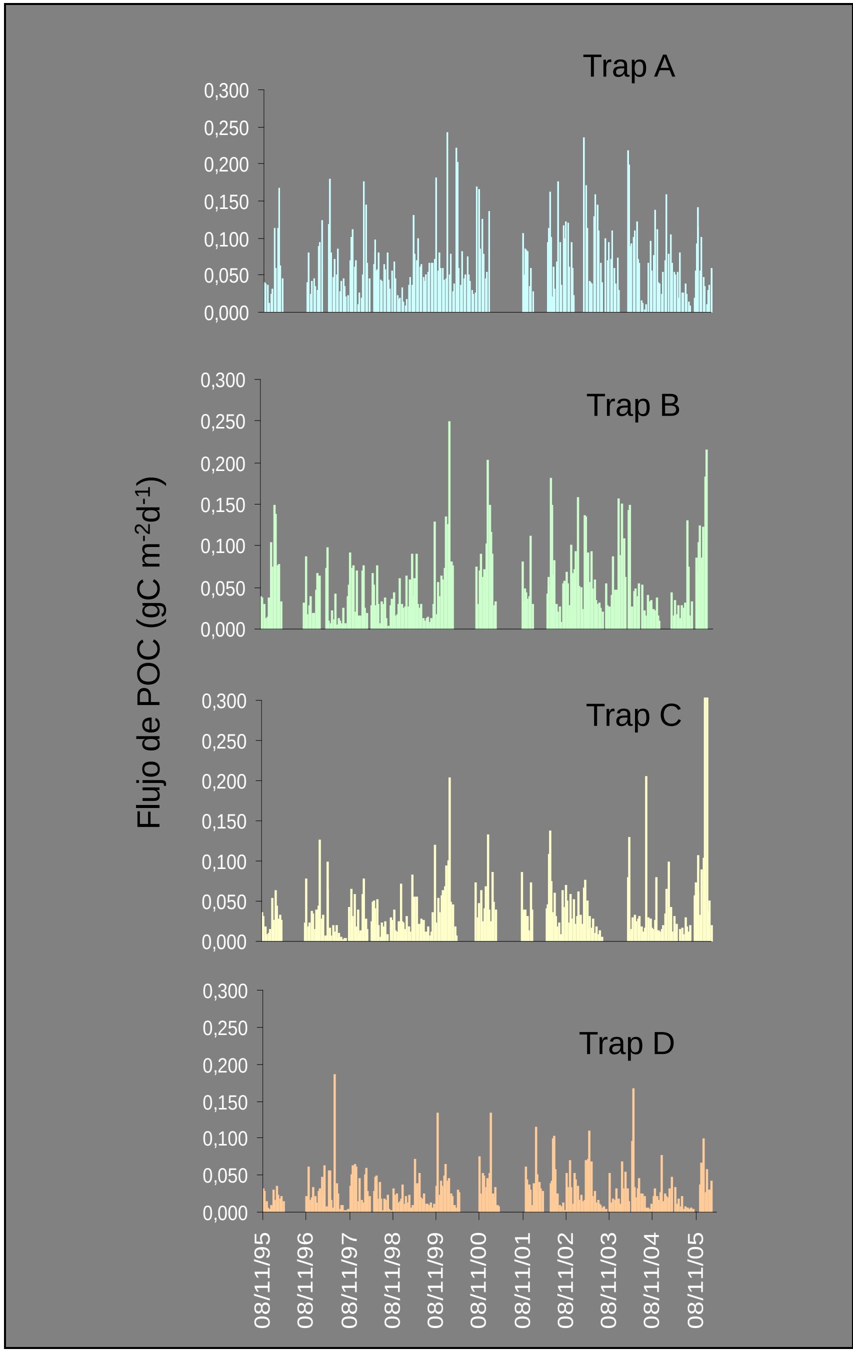
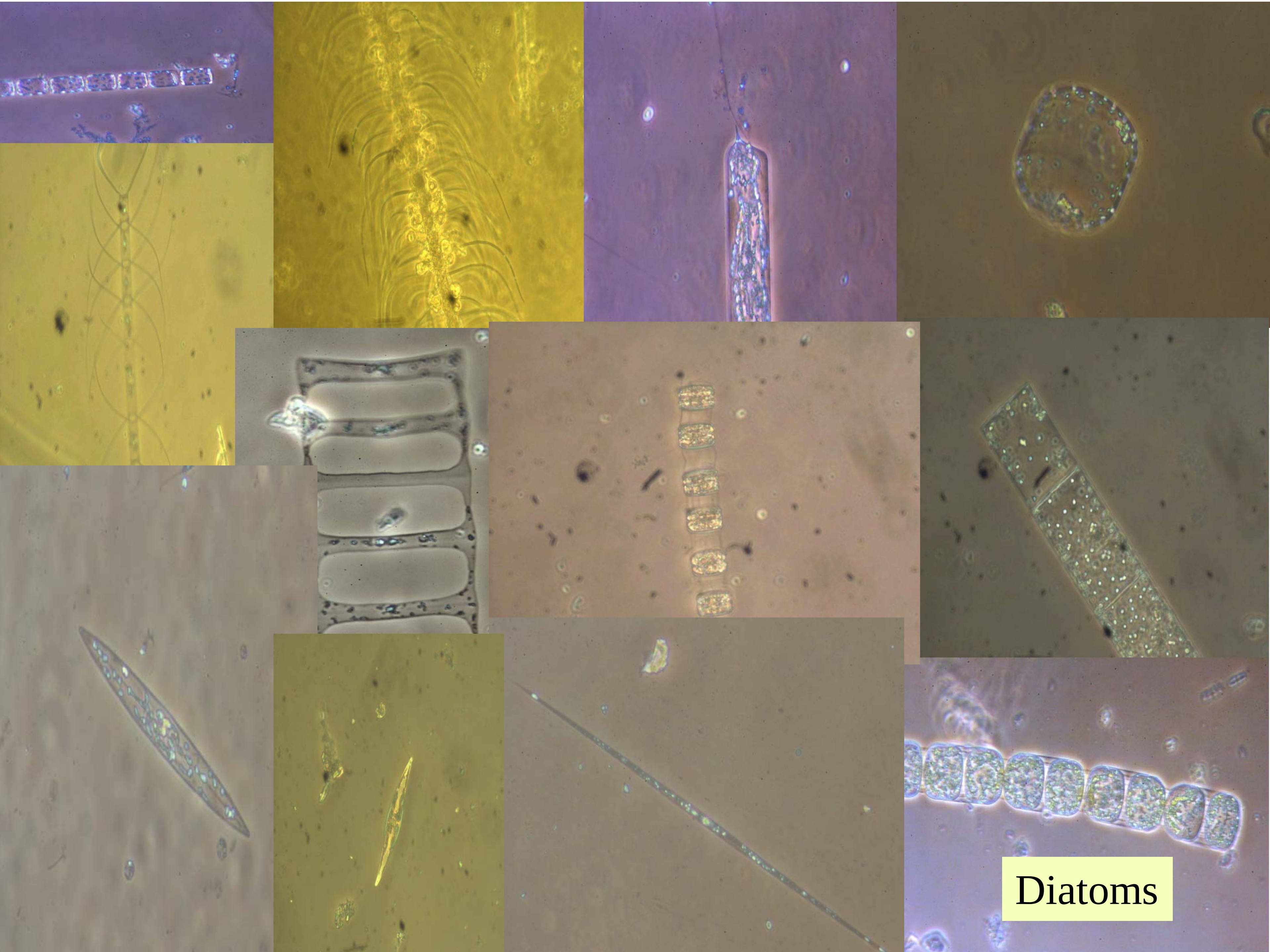
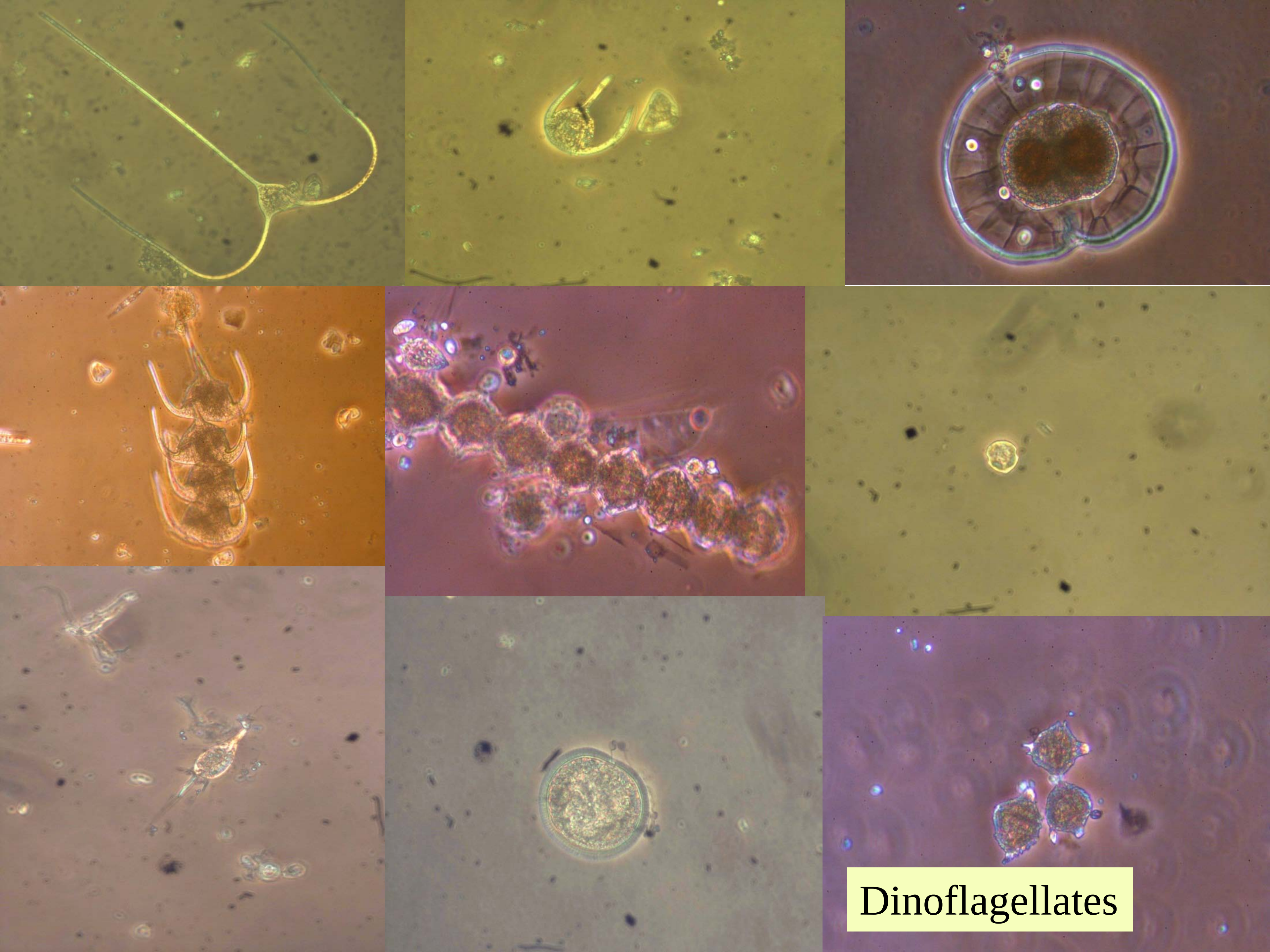
Particulate organic carbon flux

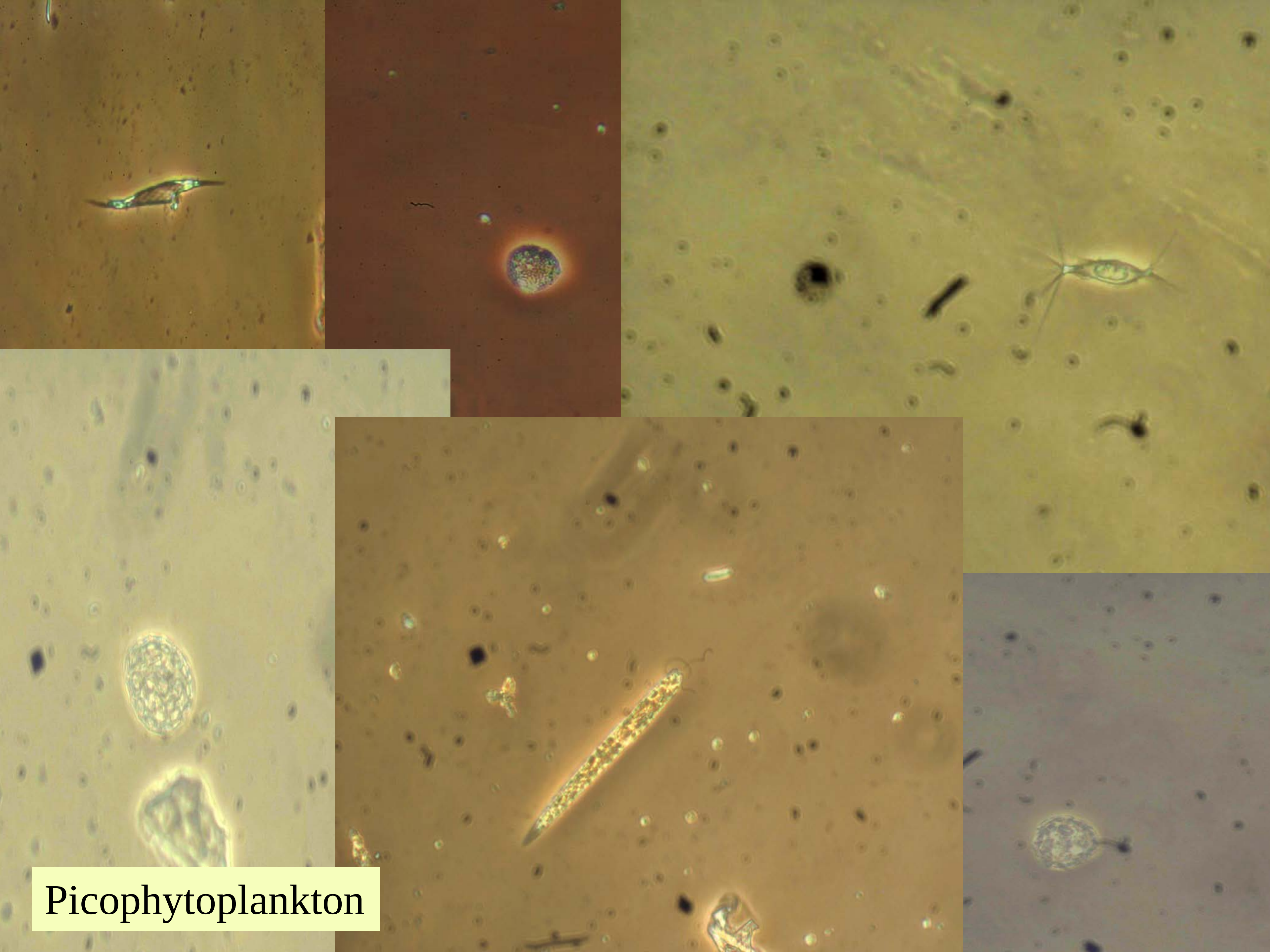
- Organic particle flux at 1300 m is:
  $\sim 5\times10^{-3}$ mol C $m^{-2}d^{-1}$ or
  ~ 0.074 g $m^{-2}d^{-1}$
  (Thunell et al., 2007)
  - ~1.3% of primary productivity reaches the bottom




Diatoms



Dinoflagellates



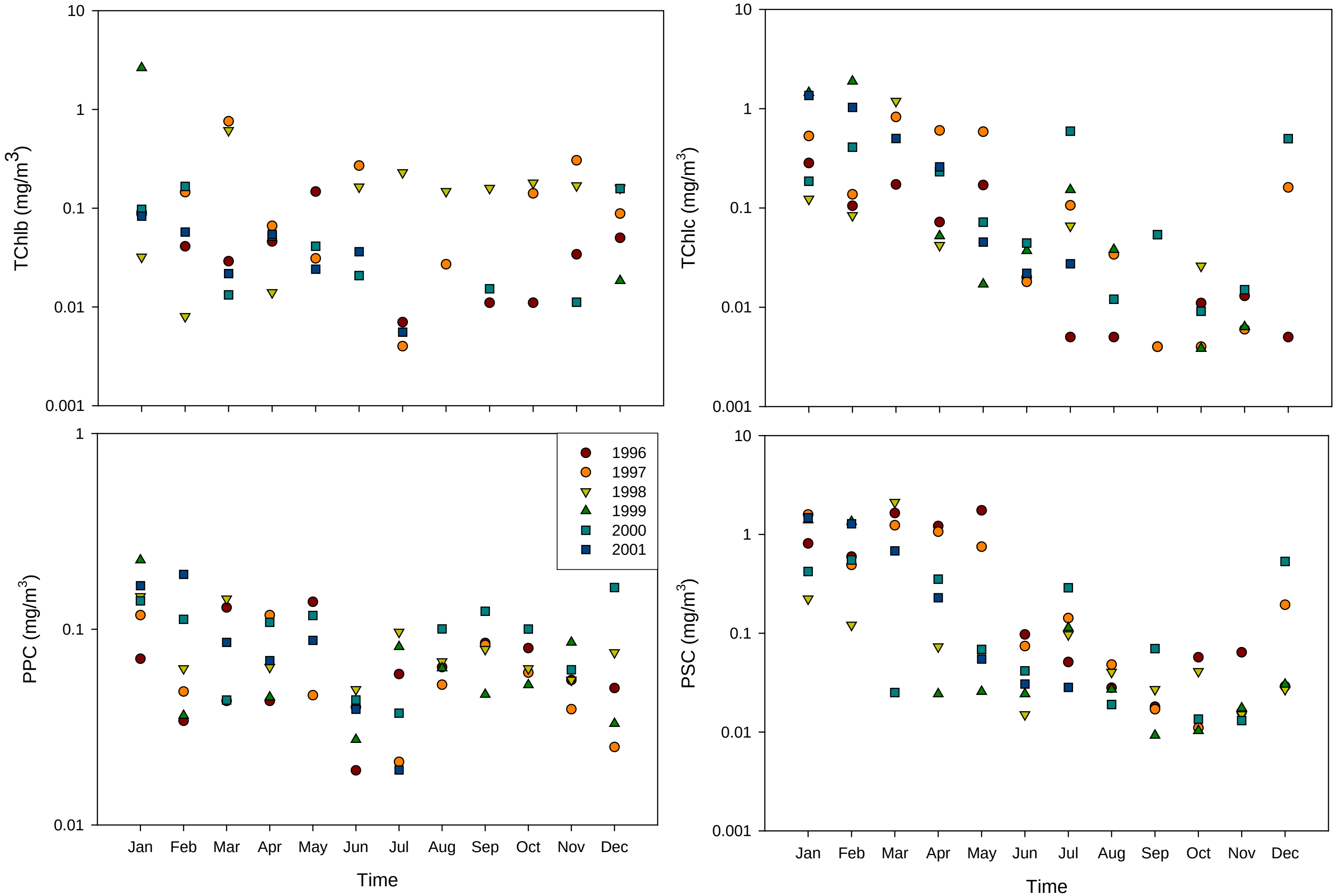
Picophytoplankton

Trichodesmium (N-fixer)

Pytoplankton pigments: HPLC

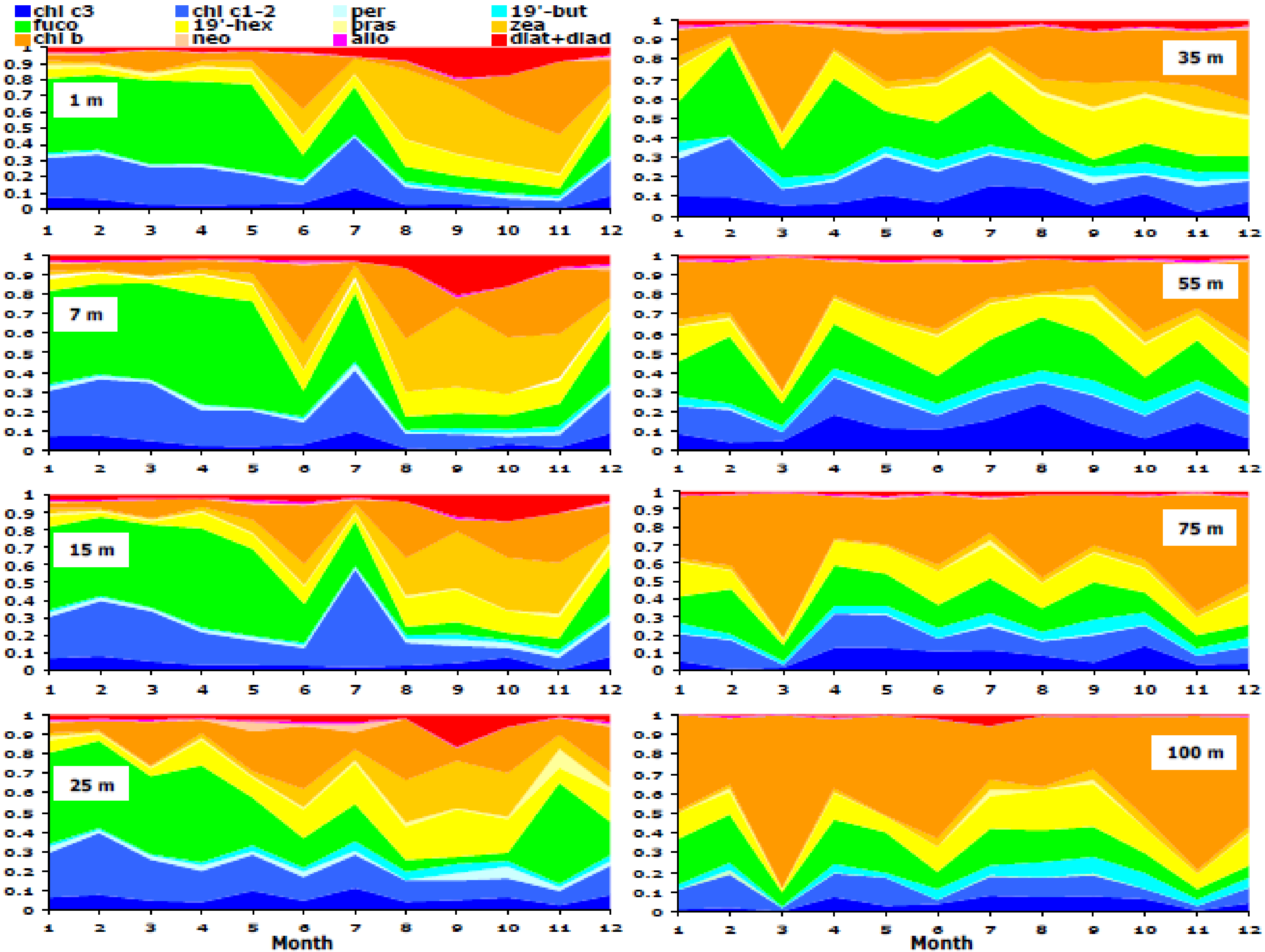
Pigment	Abbre.	Phytoplankton group/division/class
Chlorophyll c_3	Chl c_3	Prymnesiophyceae, Chrysophyceae
Chlorophyll c_{1-2}	Chl c_{1-2}	Chl c_1: Bacillariophyta, Prymnesiophyceae, Raphidophyceae Chl c_2: Cryptophyta, Bacillariophyta, Prymnesiophyceae, Raphidophyceae, Dinophyta, Chrysophyceae
Peridinin	per	Dinophyta
19'-Butanoyloxyfucoxanthin	19'-but	Prymnesiophyceae, Chrysophyceae
Fucoxanthin	fuco	Bacillariophyta, Prymnesiophyceae, Raphidophyceae, Chrysophyceae
19'-Hexanoyloxyfucoxanthin	19'-hex	Prymnesiophyceae
Prasinoxanthin	pras	Prasinophyceae
Alloxanthin	allo	Cryptophyta
Diatoxanthin+Diadinoxanthin	diat+diad	diat: trace pigment in Euglenophyta, Bacillariophyta, Prymnesiophyceae, Chrysophyceae, Raphidophyceae diad: Euglenophyta, Bacillariophyta, Prymnesiophyceae, Chrysophyceae, Raphidophyceae
Zeaxanthin	zea	Cyanobacteria, Rhodophyta, minor pigment in Chlorophyceae
Chlorophyll *b*	Chl*b*	Chlorophyceae, Prasinophyceae, Euglenophyta
Neoxanthin	neo	Chlorophyceae, Prasinophyceae
Divinyl chlorophyll *b*		Cyanobacteria (formerly Prochlorophyta)

Table 2.2. Phytoplankton signature pigments used to infer phytoplankton community composition. Based on literature review by Jeffrey and Vesk (1997).



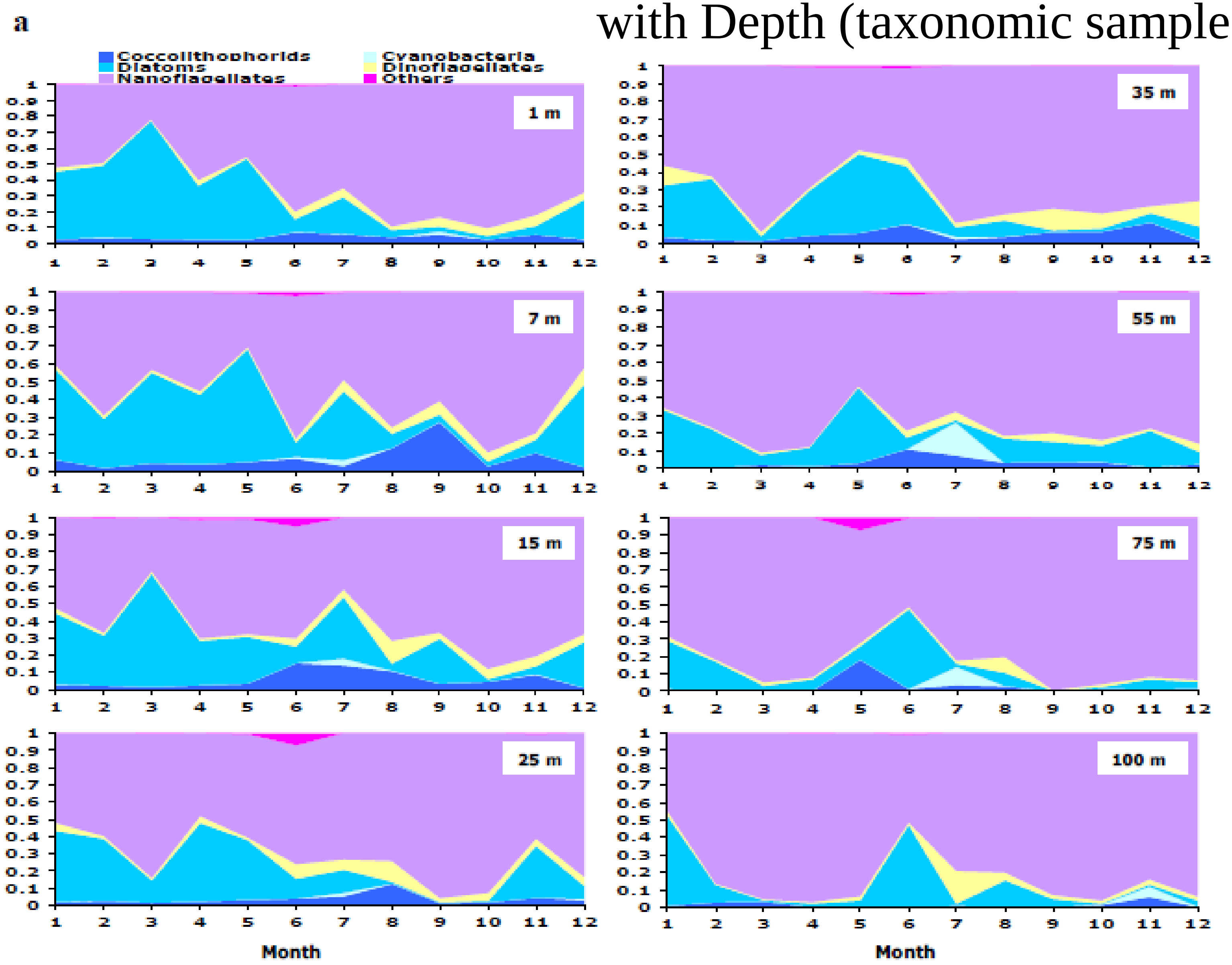
Variations in the concentration of phytoplankton accessory pigments at the CARIACO time-series station (1996 to 2001). A) Total chlorophyll-*b*, B) Photoprotective Carotenoids (PPC), C) Total Chlorophyll-*c*, D) Photosynthetic Carotenoids (PSC).

Mean (1996-2001) Seasonal Distribution of Phytoplankton Pigments with Depth (HPLC samples)



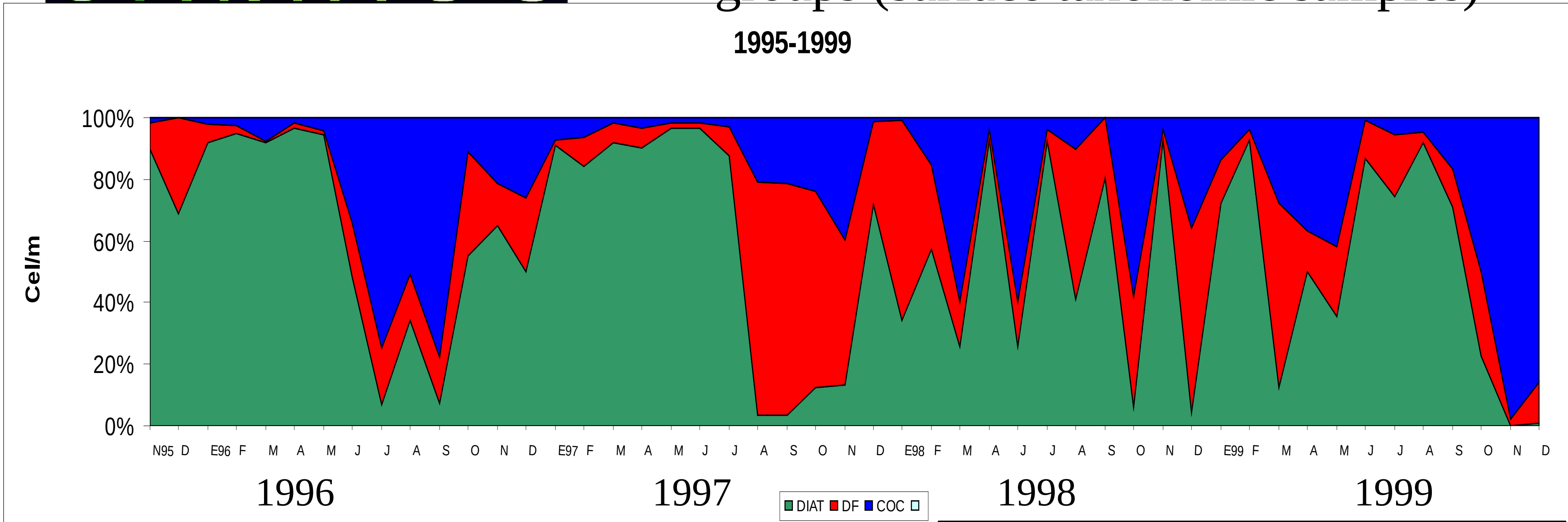
From: Natasha Rondon, MS Thesis, U Dalhousie

Mean (1996-2001) Seasonal Distribution of Phytoplankton Groups with Depth (taxonomic samples)

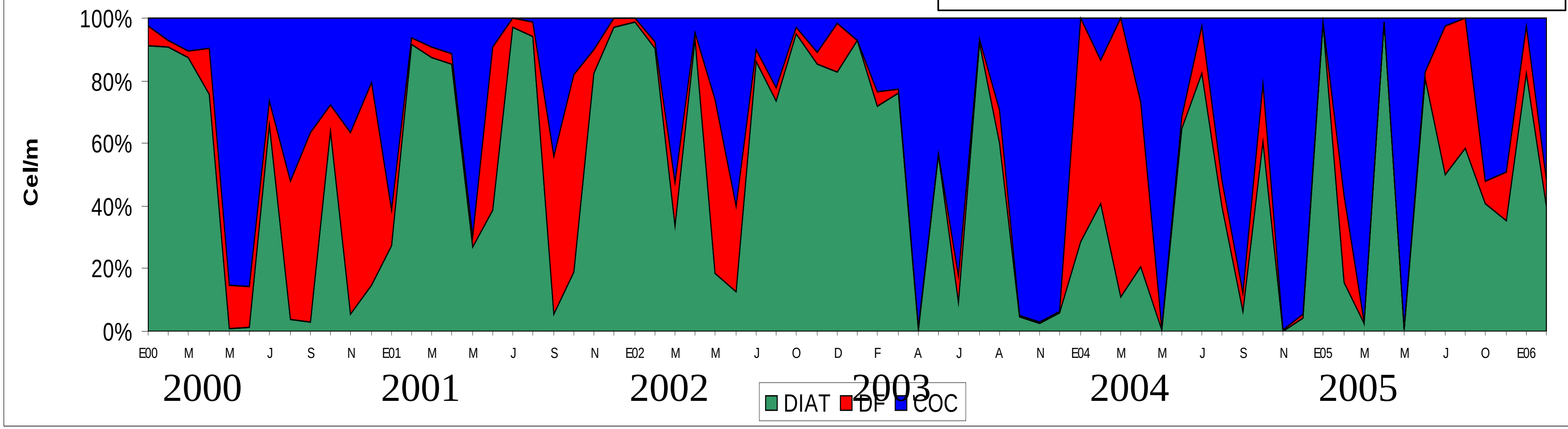


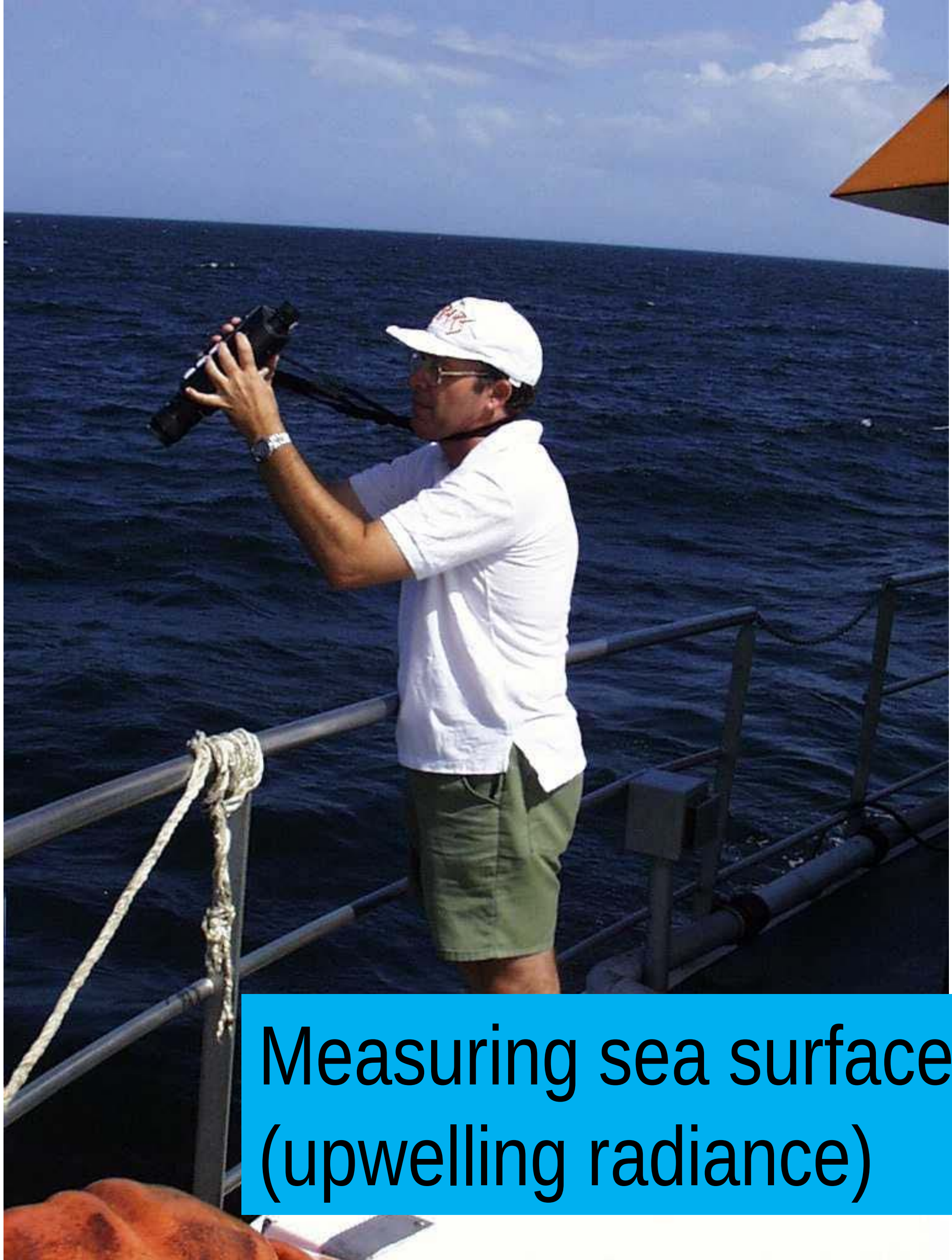
From: Natasha Rondon, MS Thesis, U Dalhousie

Interannual variability of phytoplankton groups (surface taxonomic samples)

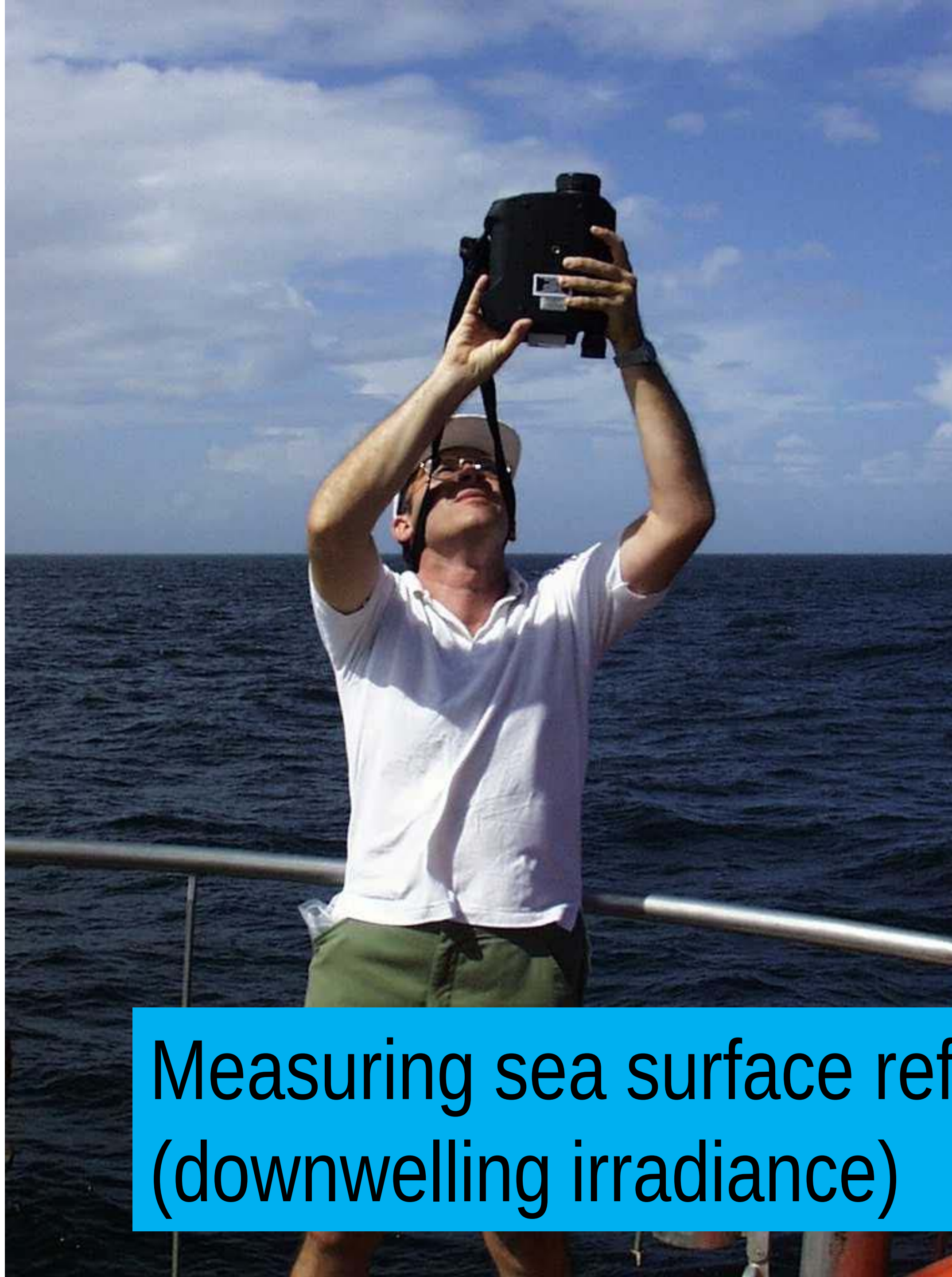


From: Luis Troccoli, Universidad de Oriente, Venezuela



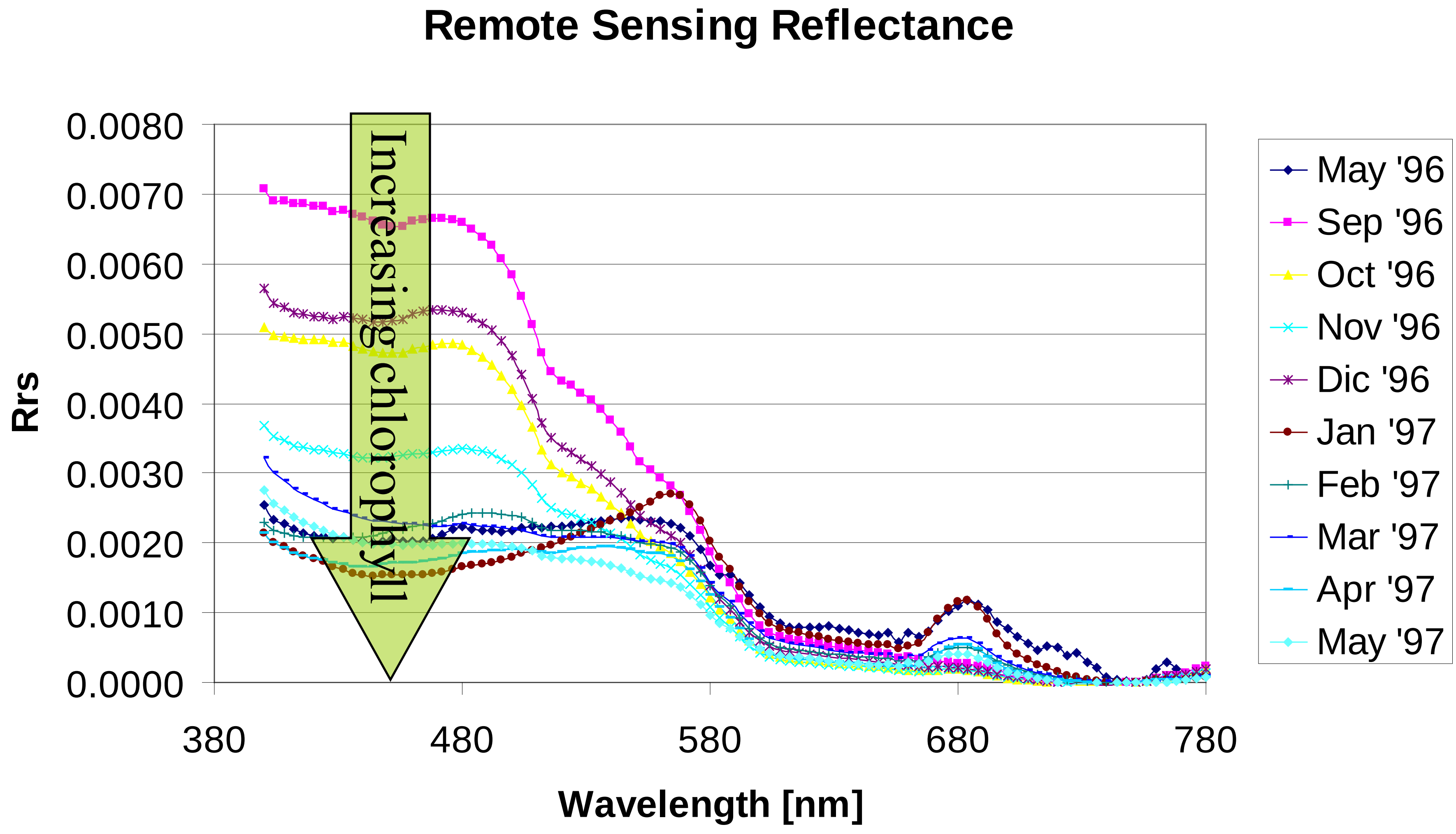


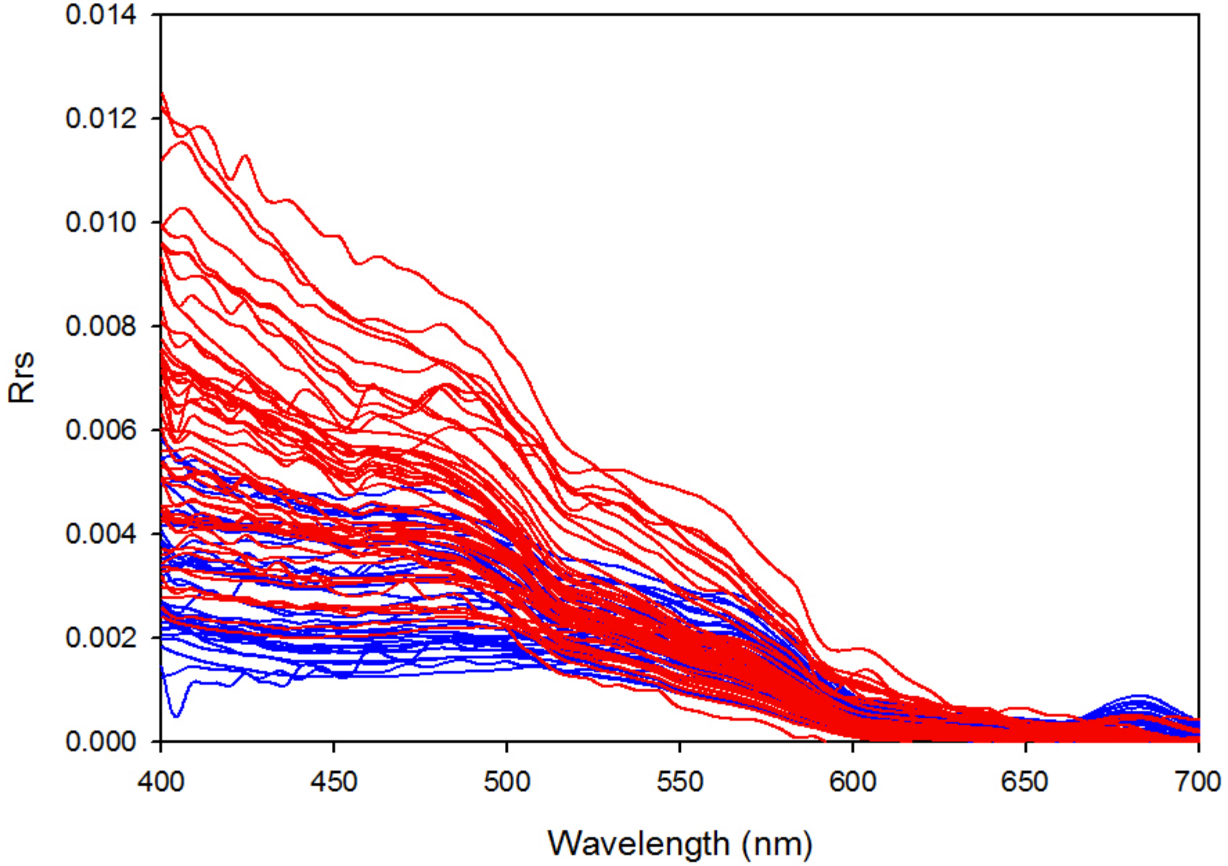
Measuring sea surface reflectance (upwelling radiance)



Measuring sea surface reflectance (downwelling irradiance)

Seasonal cycle in reflectance

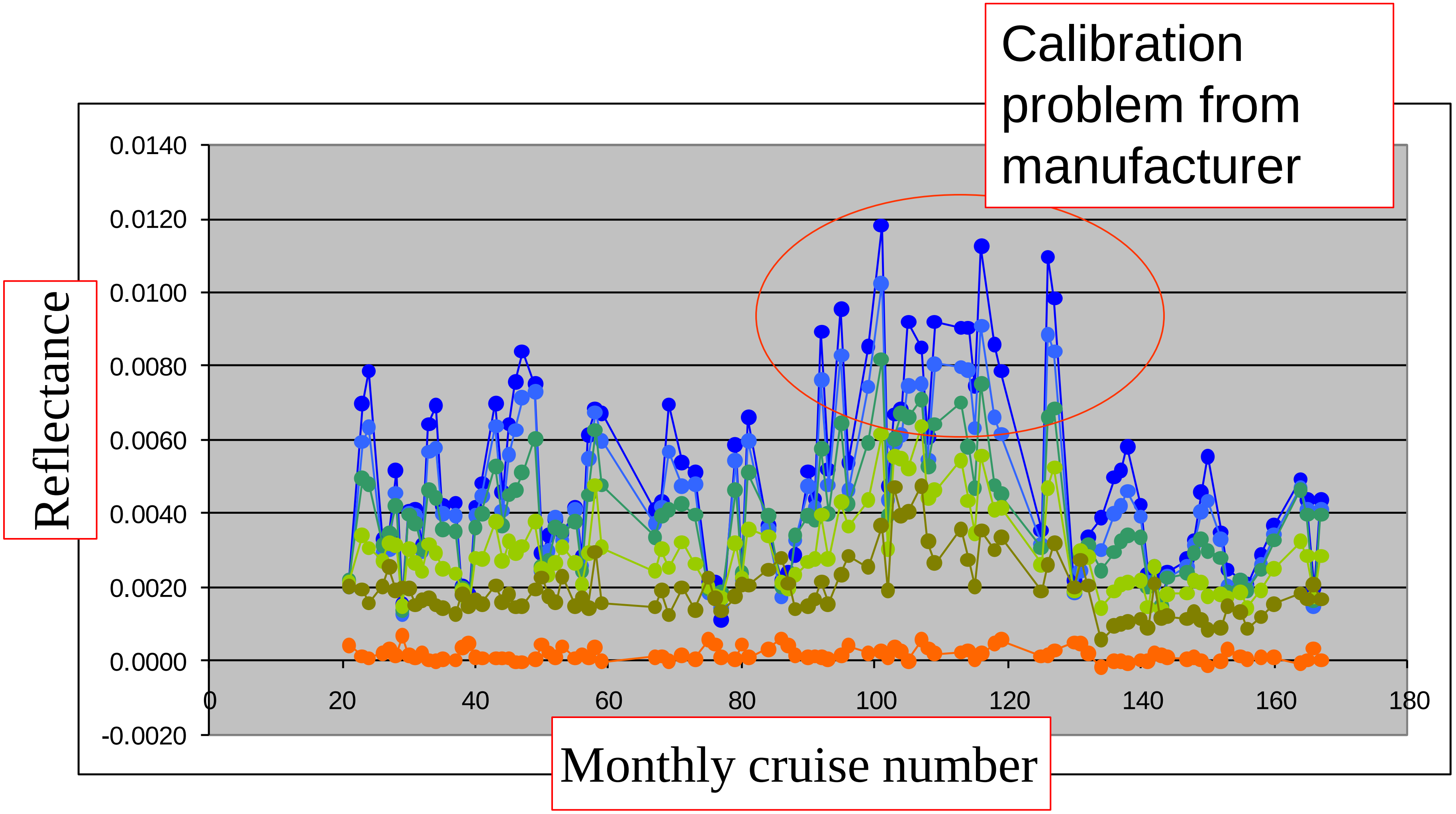


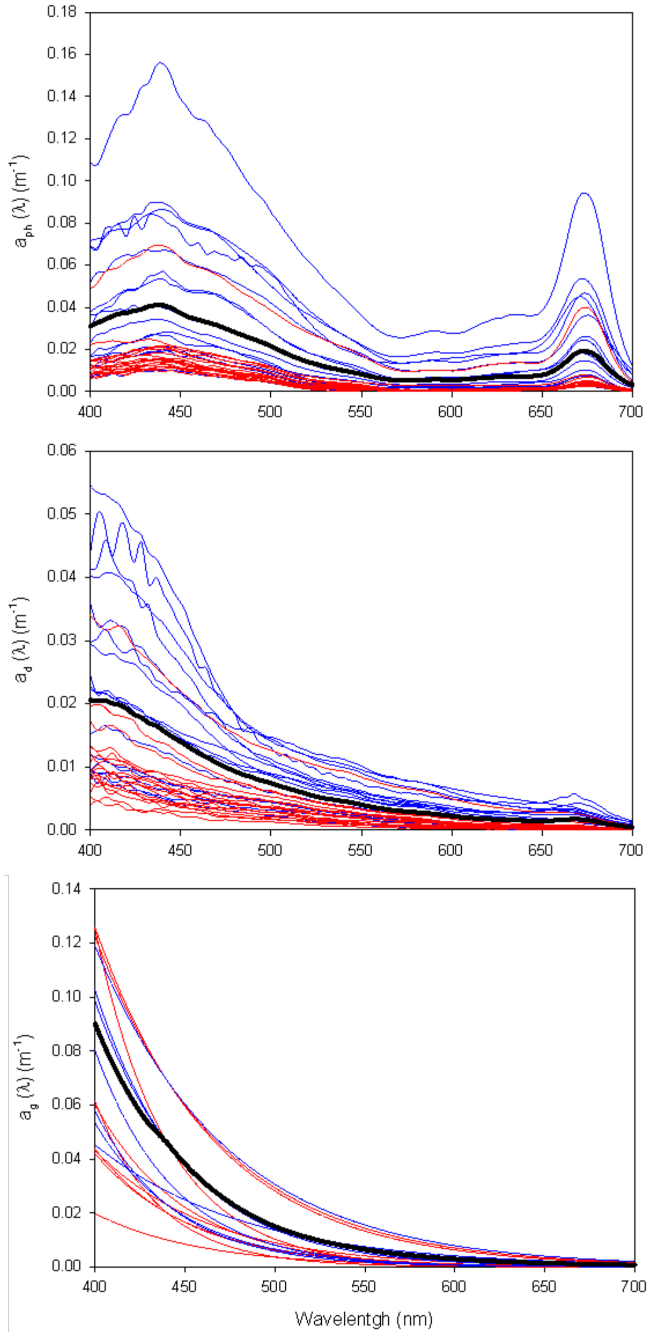


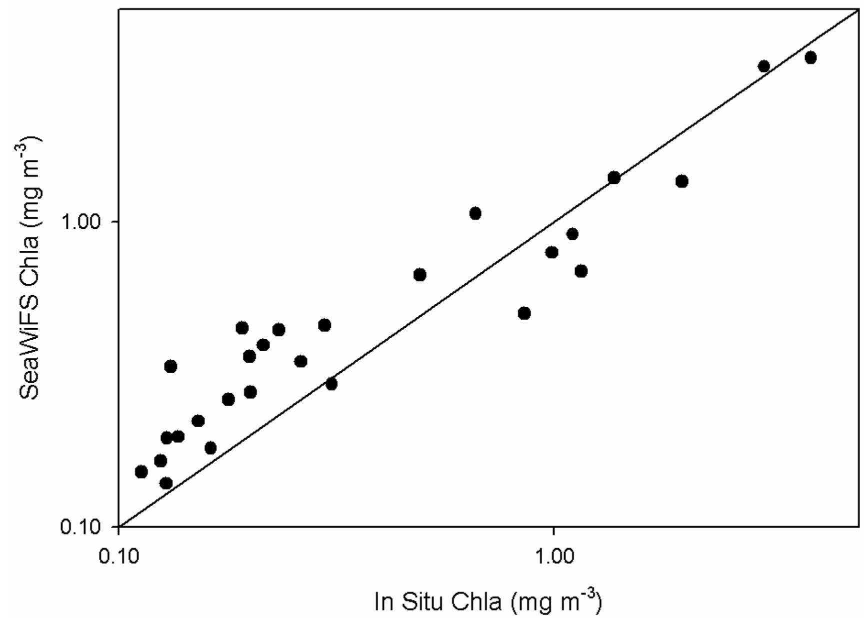
Remote sensing reflectance:

Blue: upwelling

Red: rainy season


Calibration problem from manufacturer
Reflectance
0.0140
0.0120
0.0100
0.0080
0.0060
0.0040
0.0020
0.0000
-0.0020
0
20
40
60
80
100
120
140
160
180
Monthly cruise number





Concurrent 1 km2 SeaWiFS-derived chlorophyll-*a* estimates compared to *in situ* Chlorophyll *a* observations between January 1998 and December 2005 at the Cariaco time-series station (N = 29, R2=0.84, RMSE=57%). Solid line is the 1:1 relationship.

Absorption spectra
(a) phytoplankton,
(b) detrital material and
(c) CDOM
Blue: upwelling / Red: rainy season
Black: average values.

Much work to be done:

Post-doc wanted!

Some Key Findings

Community shifts:

Trade Winds decreased between 2001-2005 relative to 1996-2000:
-seasonal upwelling intensity decreased
-waters have become warmer
-annual PP remains about the same
-phytoplankton community shift from large diatoms to smaller cells
-coincides with regional fishery collapse (sardine)

2006-2008 upwelling seems to have increased, but not sardine fisheries

We should expect similar cases of interannual variability and long-term trends everywhere around the world – at this time we are unable to assess these changes or their impacts on either foodwebs, biogeochemistry or climate

Observations

Implications for future satellite programs / HyspIRI:

-Initiate planning for a comprehensive cal/val program, building on NASA SIMBIOS/SeaBASS experience
-Initiate planning for ecosystem assessments: land-ocean interactions
-Include time series efforts with relevant observations
-Coordinate with PACE/ACE, Geo-Cape teams

This will lead to:

-Interdisciplinary scientific understanding of the coastal zone including human activities.
-A practical classification for coastal habitats and the valuation of ecosystems services
-Quantify the distributions and biological diversity of coastal habitats and their changes
-Better assessment of carbon and nutrient cycling and sequestration in coastal habitats
-Identification of hot-spots of habitat diversity for use in setting priorities for restoration and conservation

CARIACO

<u>CARIACO and its people</u>

FLASA/EDIMAR

FONACIT

NSF

Many others