The CARIACO Oceanographic Time Series Program:

Studying linkages between oceanographic conditions and past climate changes

The CARIACO Team

UNIVERSITY OF SOUTH FLORIDA
COLLEGE OF MARINE SCIENCE

Institute for Marine Remote Sensing

Acknowledgements

- ***Colleagues and co-Investigators:***
  - *Frank Muller-Karger*
  - *Ramon Varela (FLASA)*
  - *Yrene Astor (FLASA)*
  - *Eduardo Klein (USB)*
  - *Robert Thunell (USC)*
  - *Mary Scranton (SUNY)*
  - *Gordon Taylor (SUNY)*
  - *Robert Weisberg (USF)*
  - *Kent Fanning (USF)*
  - *Laura Lorenzoni*
  - *Digna Rueda*
  - *Enrique Montes*
  - *[AND MANY OTHERS including students, technicians]*

- ***Funding and support:***
  - *NSF*
  - *FONACIT*
  - *FLASA*
  - *USB*
  - *UCV*
  - *UDO*

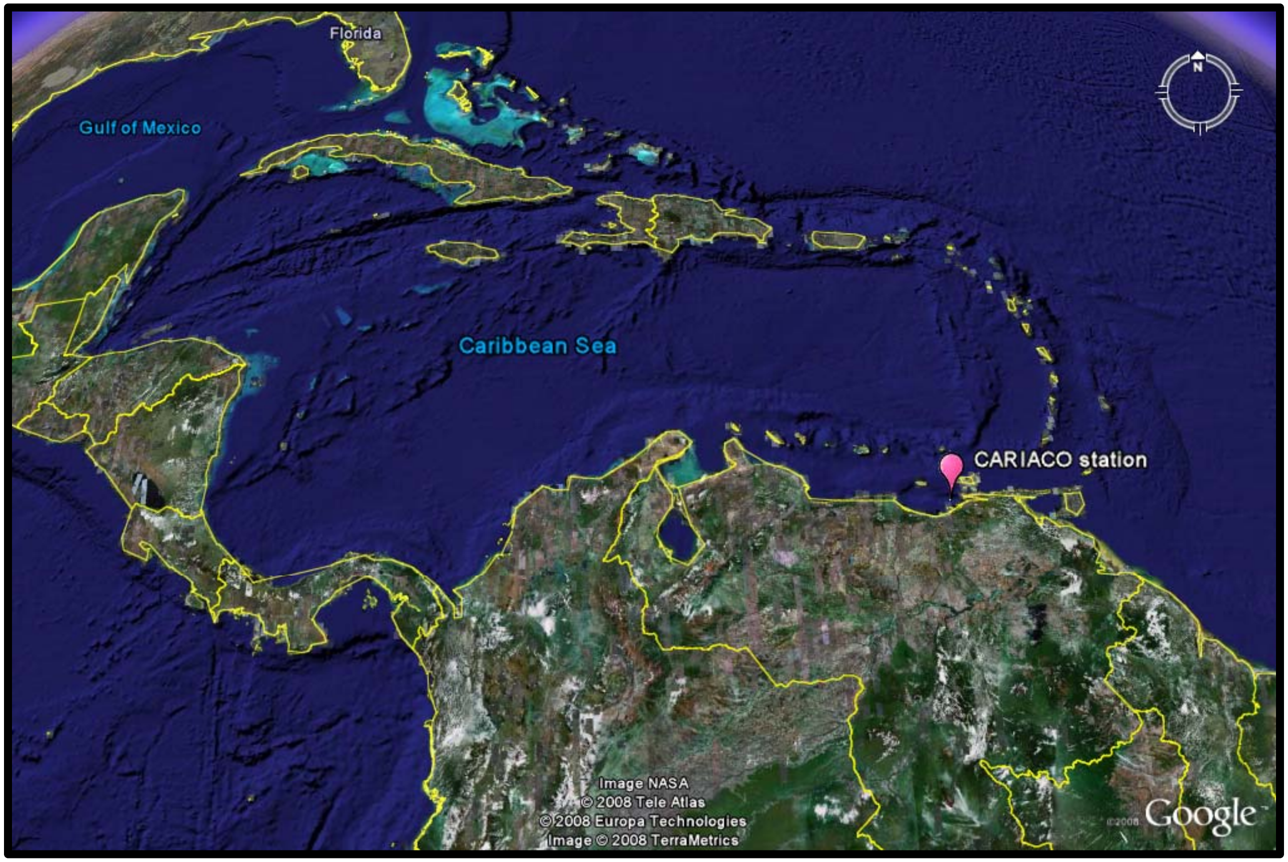
Location

Cariaco Basin

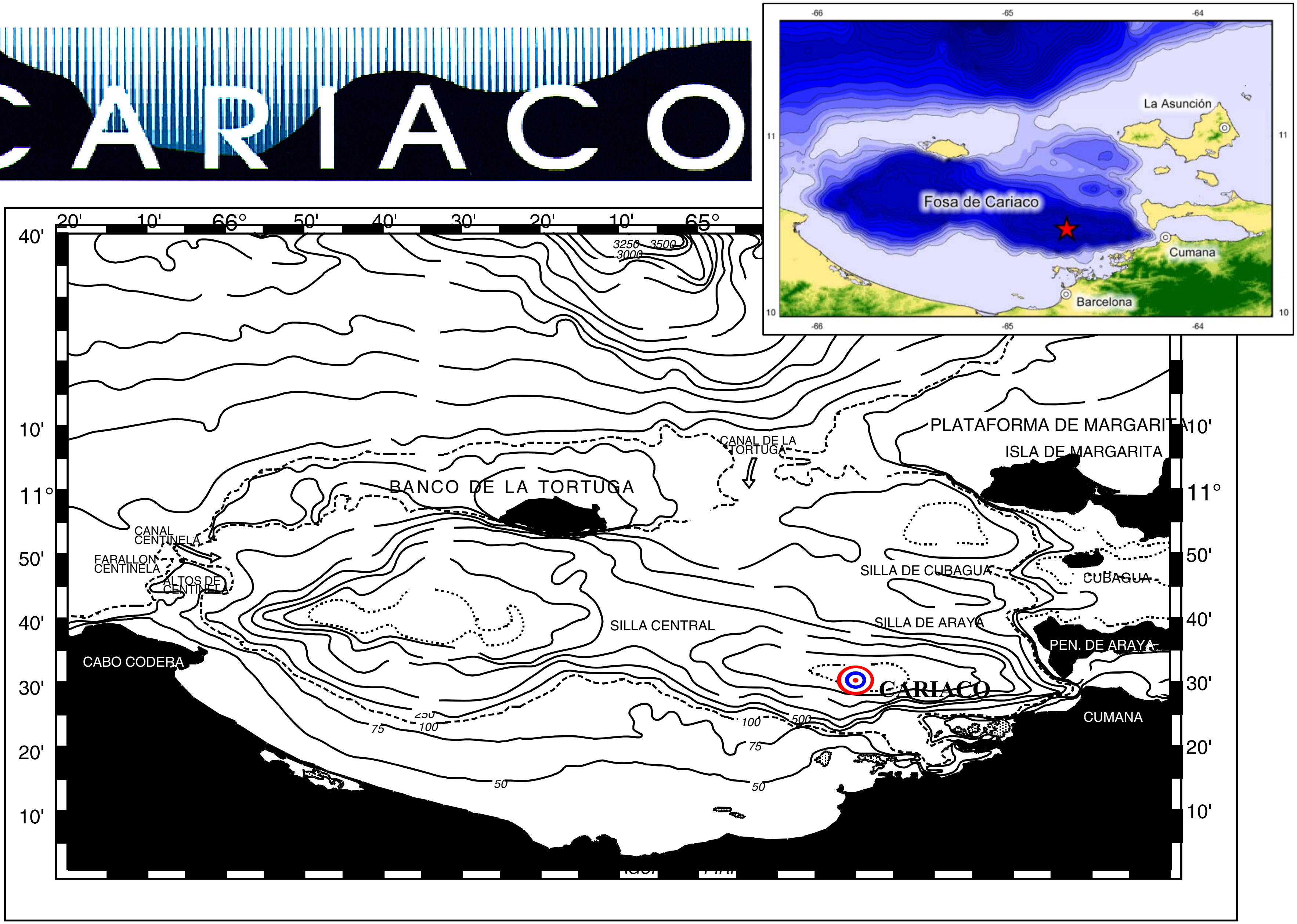
Southeastern Caribbean

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

~1400 m



CARIACO



Fosa de Cariaco
La Asunción
Cumana
Barcelona
-66
-65
-64
11
10
20'
10'
66°
50'
40'
30'
20'
10'
65°
40'
10'
11°
50'
40'
30'
20'
10'
3250
3500
3000
PLATAFORMA DE MARGARITA
ISLA DE MARGARITA
CANAL DE LA TORTUGA
BANCO DE LA TORTUGA
CANAL CENTINELA
FARALLON CENTINELA
ALTOS DE CENTINELA
SILLA DE CUBAGUA
CUBAGUA
SILLA CENTRAL
SILLA DE ARAYA
PEN. DE ARAYA
CABO CODERA
CARIACO
CUMANA
250
100
75
50
500

Cariaco Basin Characteristics

Tropical climate / strong Intertropical Convergence Zone (ITCZ) influence

Alternating seasonal upwelling and river discharge

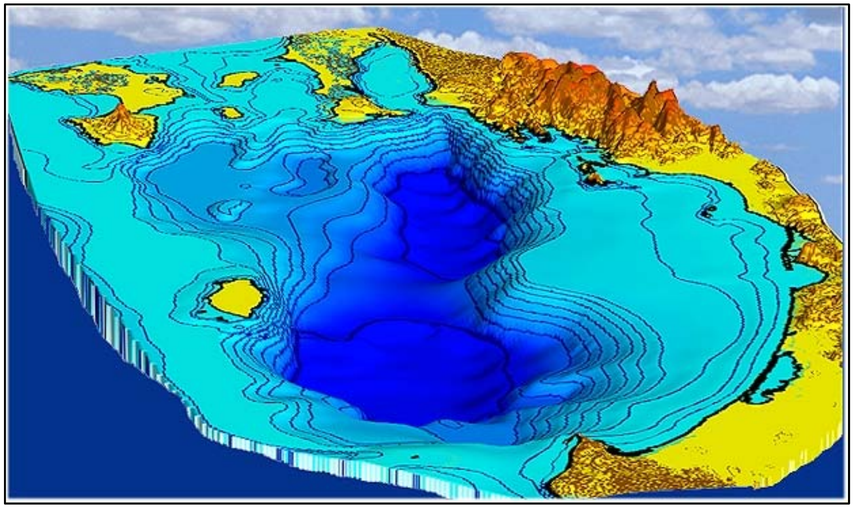
Basin embedded in the continental shelf.

High primary production (>400 gC/m2/y)

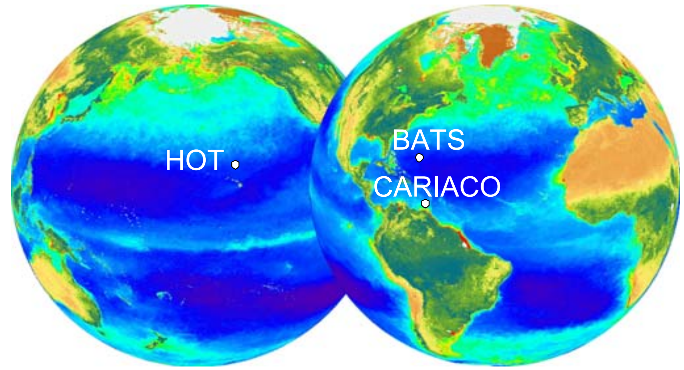
Permanent **anoxia** below ~250m: undisturbed sediments.

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

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



CARIACO



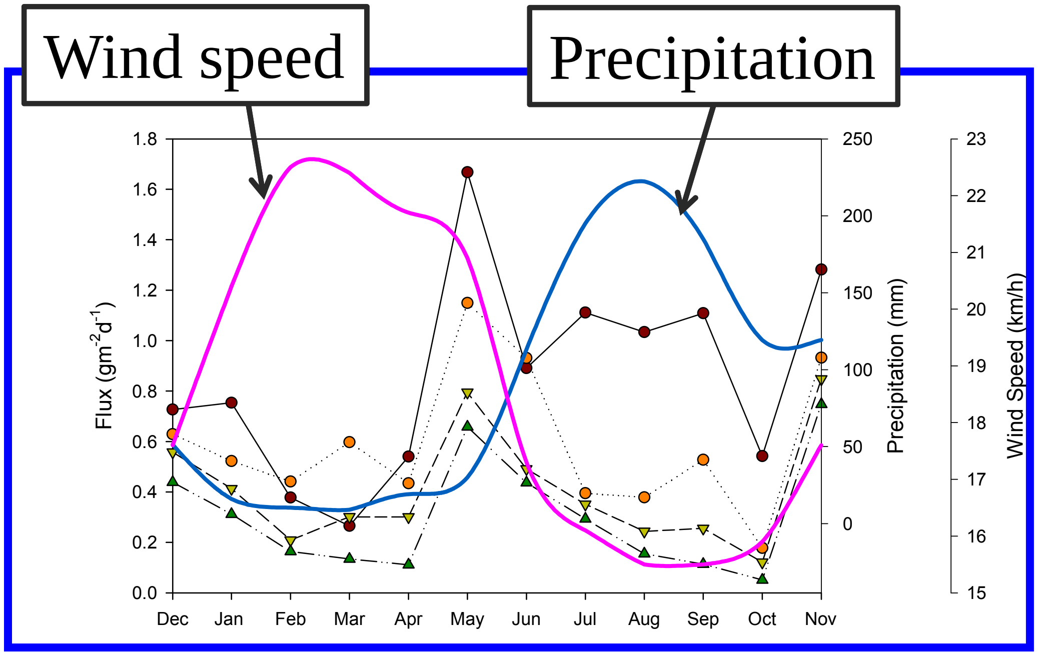
Comparison of BATS, HOT and CARIACO

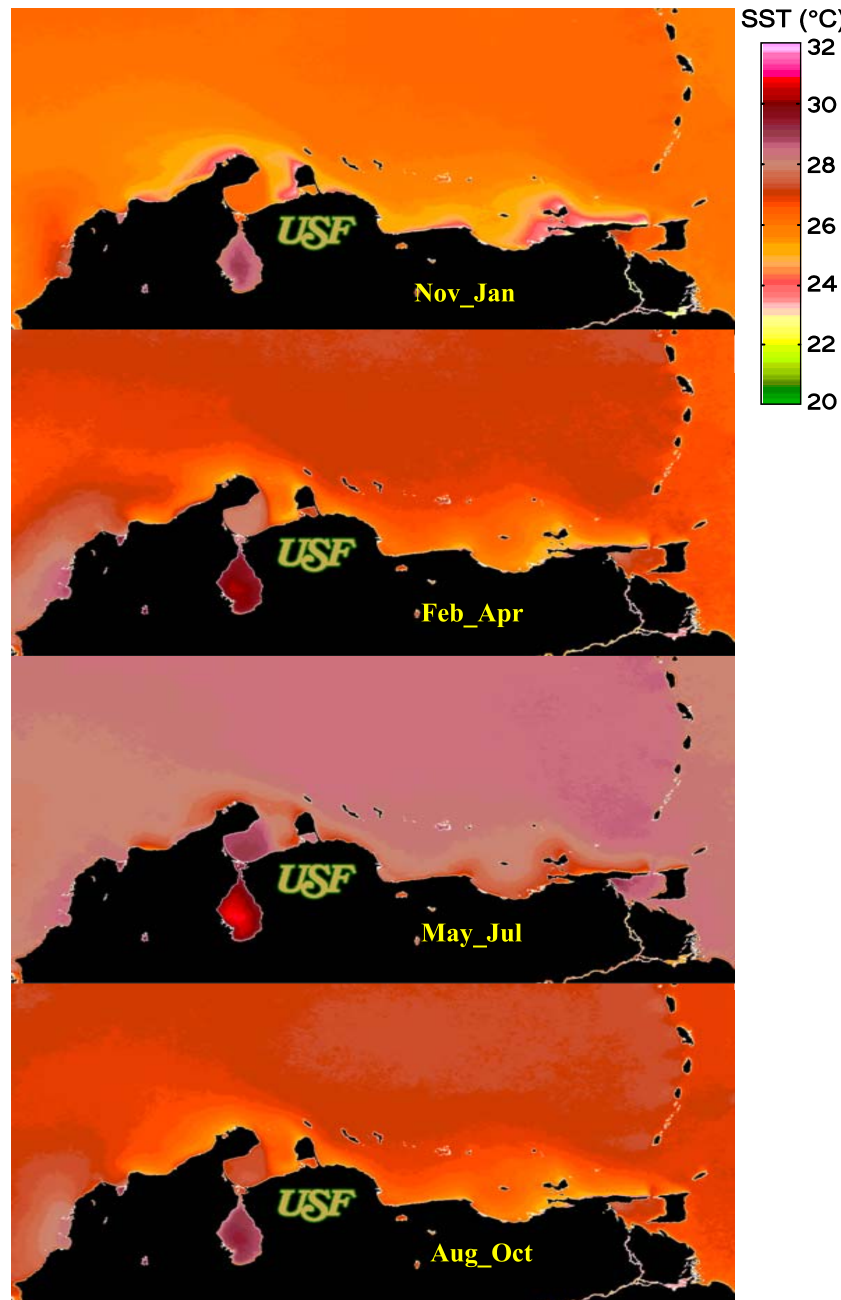
Parameter	BATS* (11 years)	HOT* (11 years)	CARIACO (13 years)
Prim. Prod. (mg C m^{-2} d^{-1})	416 111 to 1039	480 184 to 923	1461 348 to 6858
Carbon Flux (mg C m^{-2} d^{-1})	27.2 8.7 to 76.1	28.3 10.7 to 57.0	65.5 9.1 to 249.2
Export Ratio	0.072 0.016 to 0.214	0.062 0.020 to 0.149	0.066 0.007 to 0.250

*from Karl et al., 2001

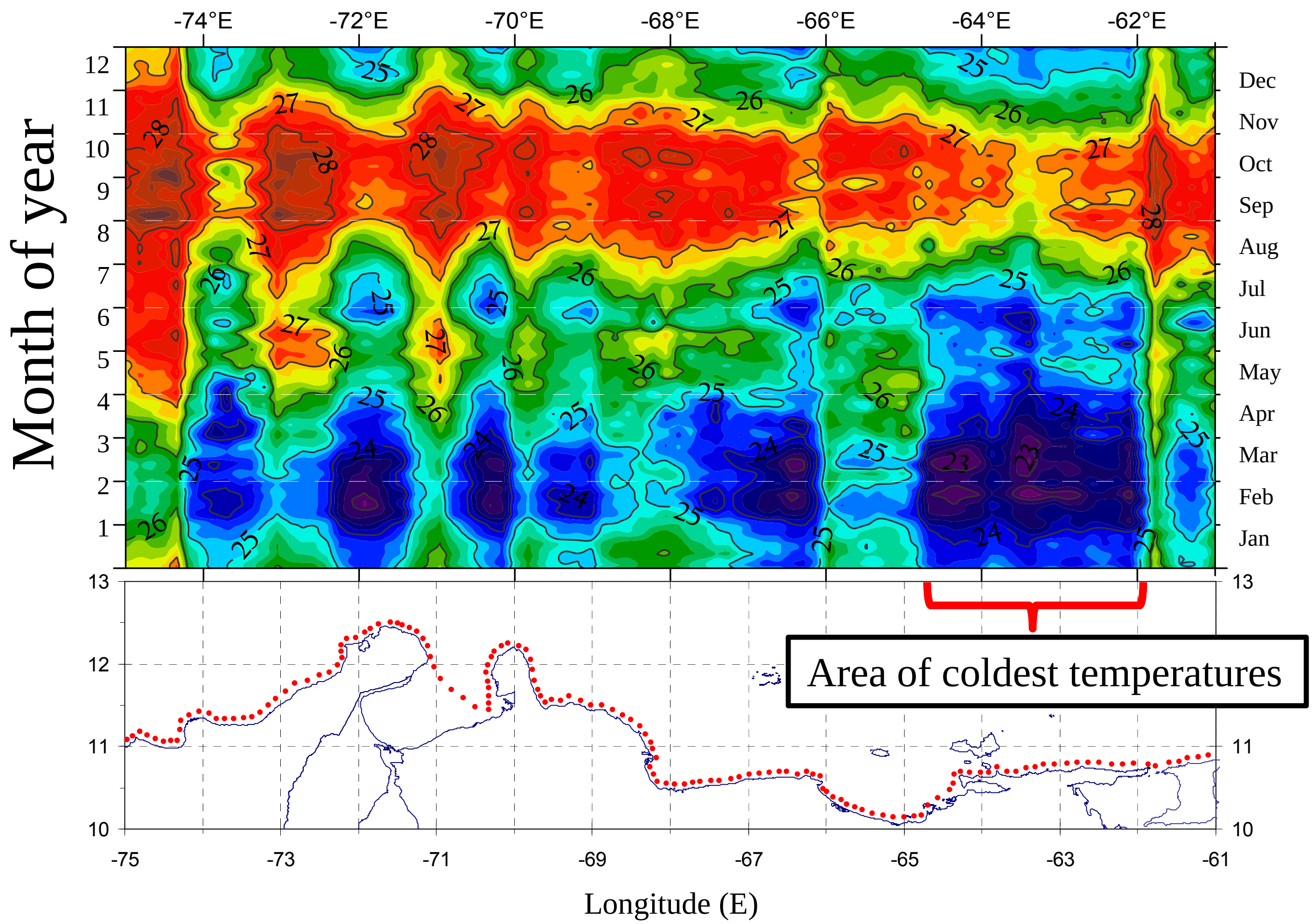
Driving forces:

ITCZ and Atlantic circulation





Sea Surface Temperature



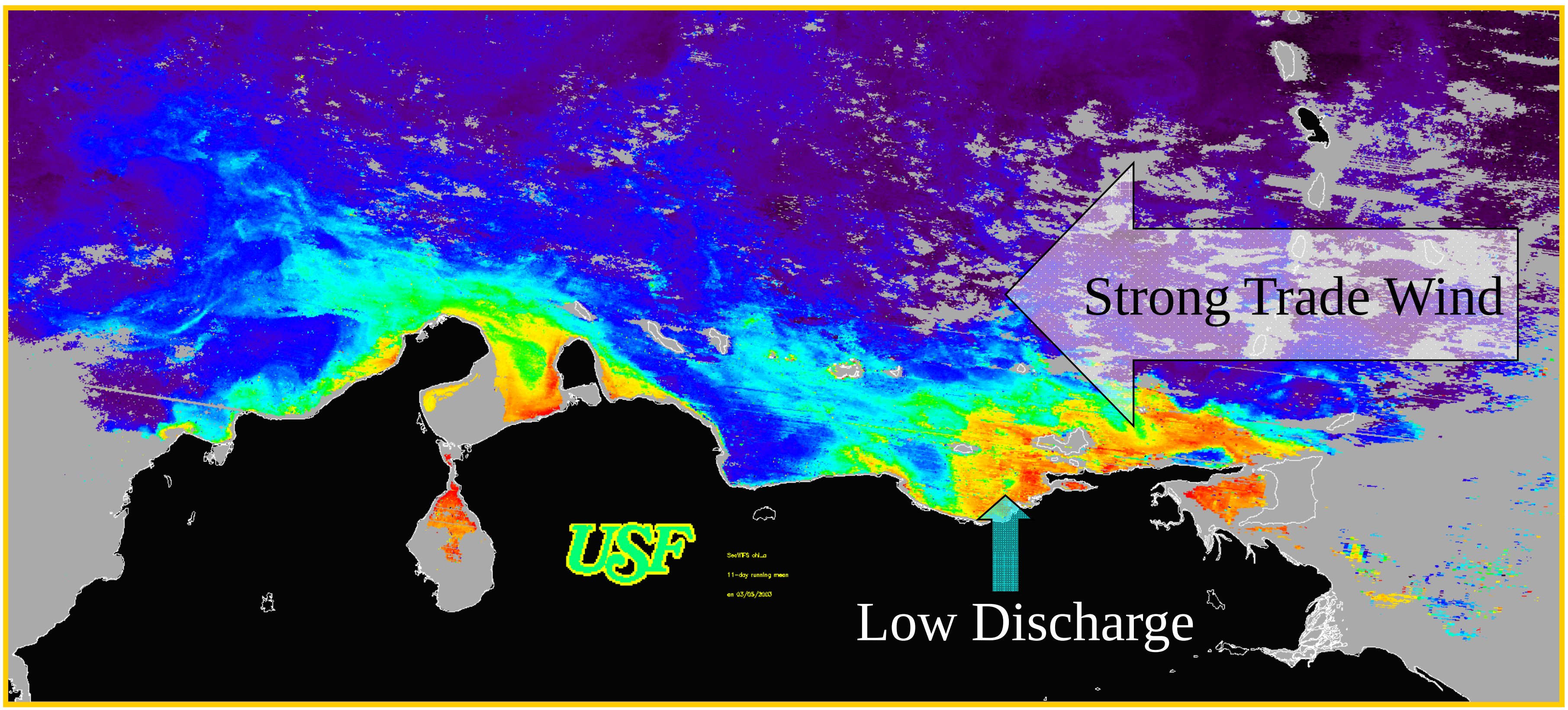
Monthly Sea Surface Temperature (SST) climatology from satellite observations

CARIACO

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

Mar 5, ’03

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



CARIACO

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

Oct 17, ‘03

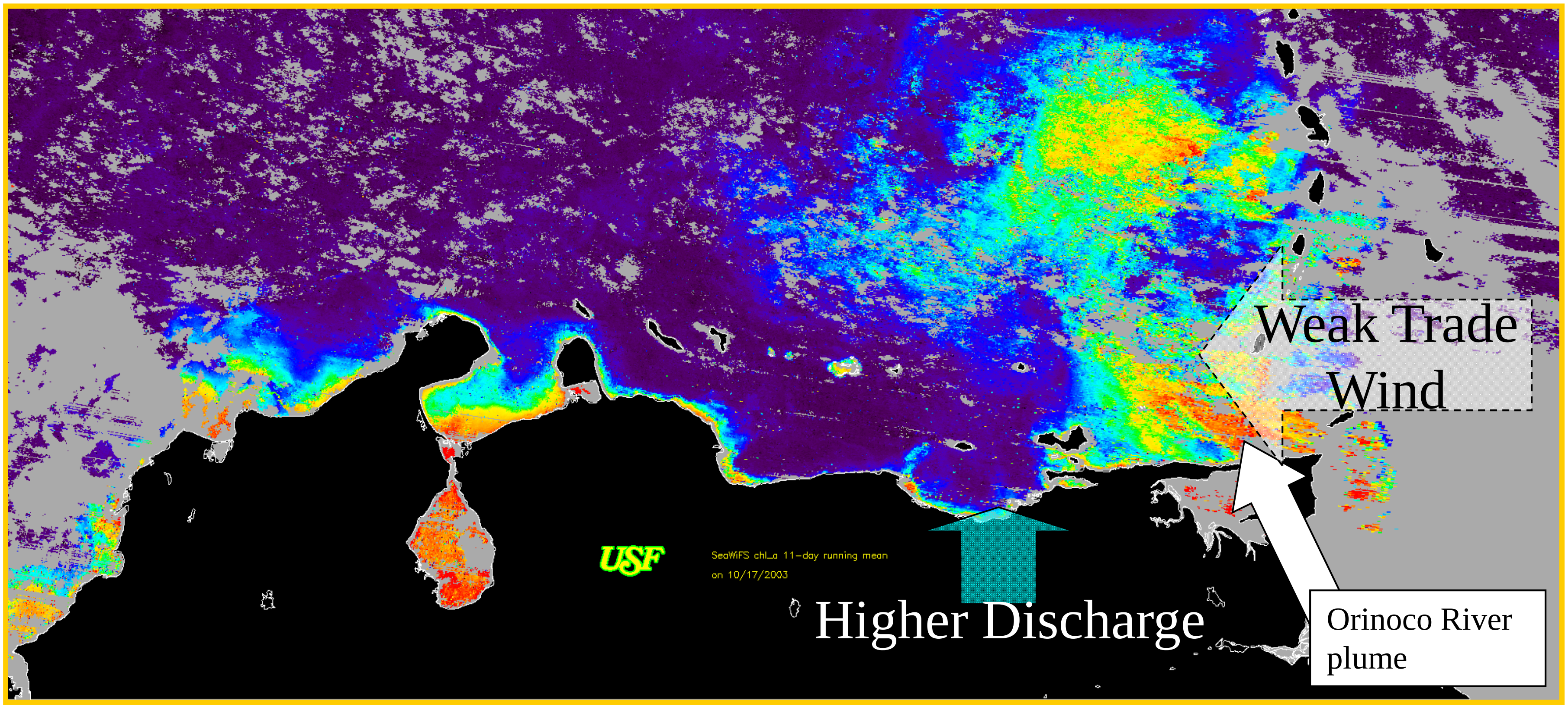
<u>Second half of year</u>:

Less wind / wet

Low upwelling

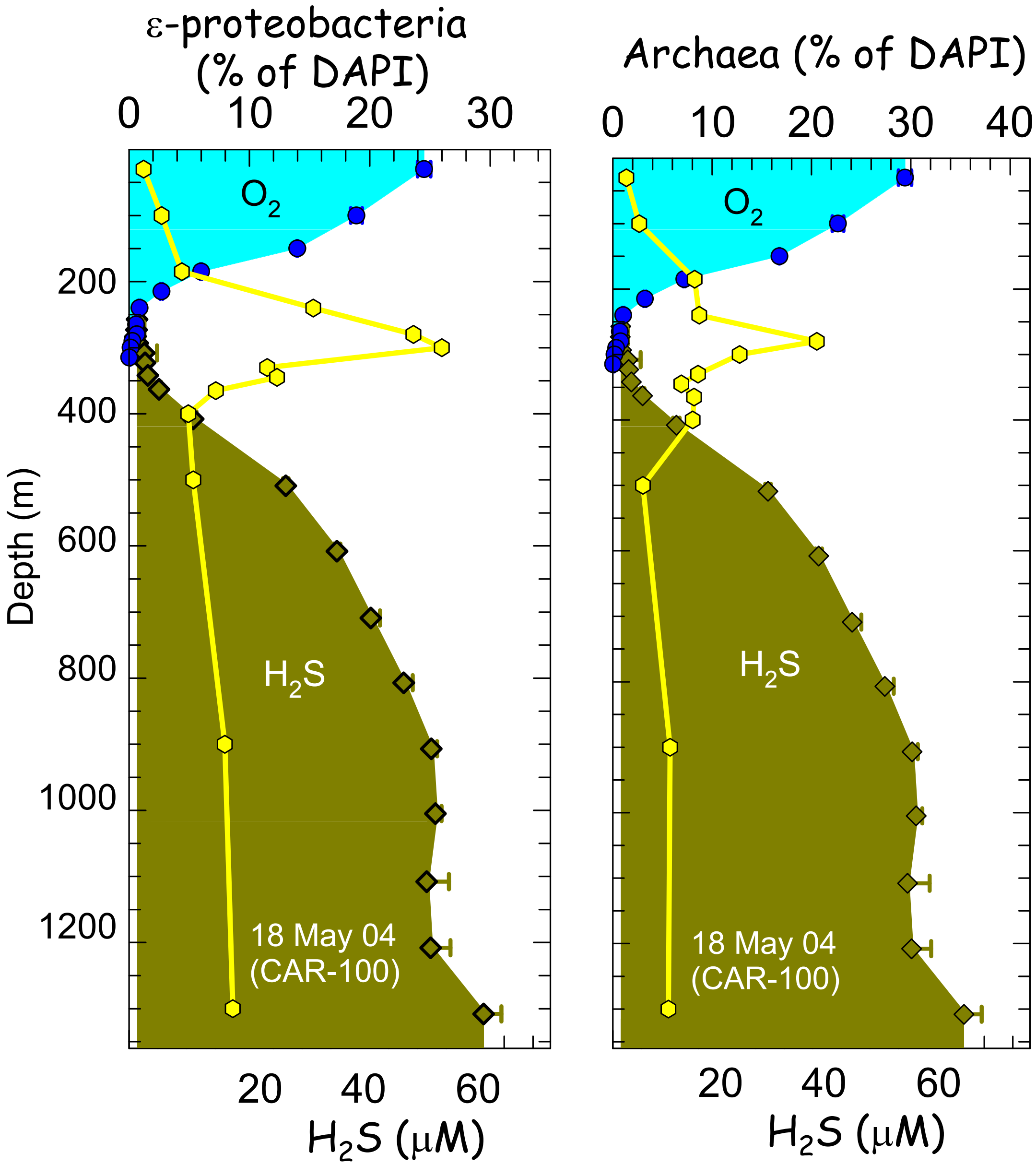
Low primary production

High river discharge



Cariaco Basin is anoxic below ~240 m

Chemoautotrophs present in the transition and anoxic zones



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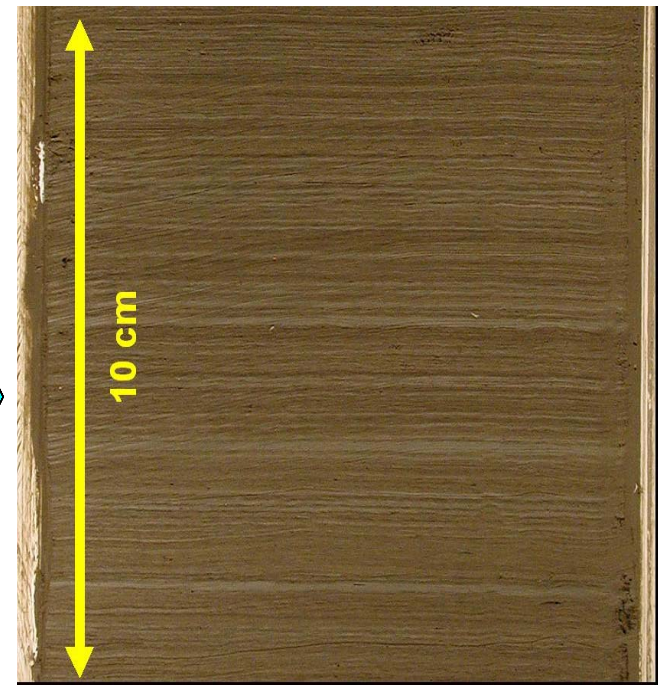
No benthic organisms

Laminated (“varved”) sediments



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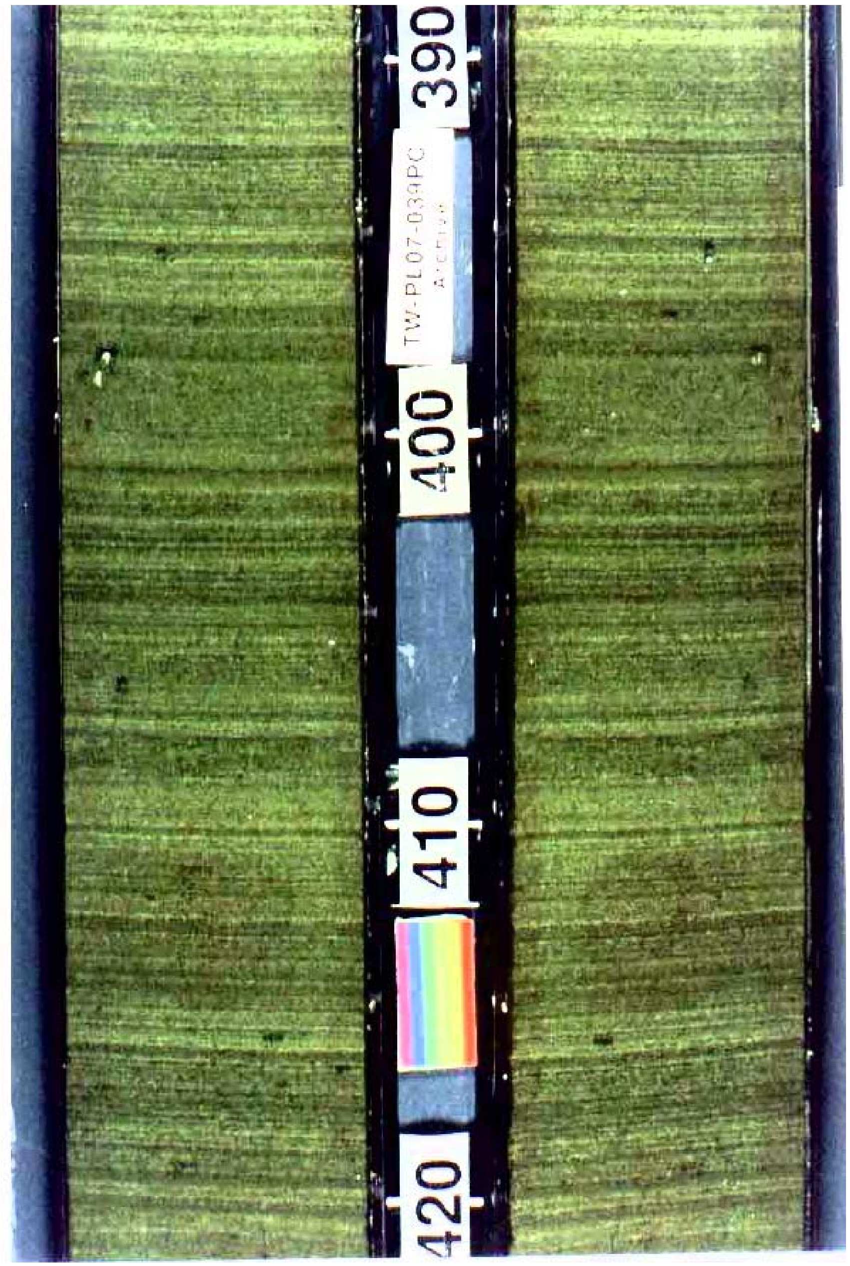
Sediment varves:

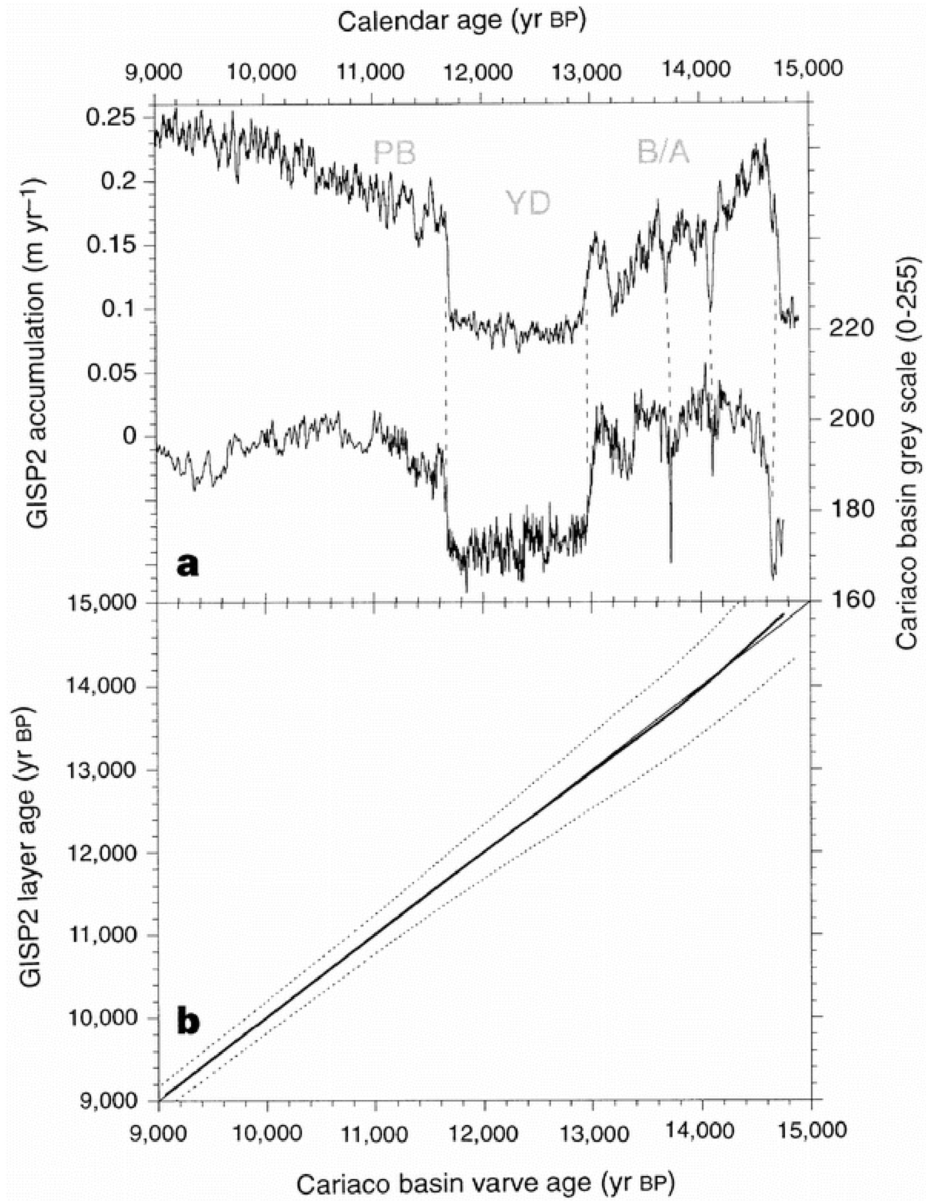
- *Lighter color laminae:*
  - *rich in plankton*
  - *(upwelling period)*
- *Dark laminae:*
  - *Riverine*
  - *detrital minerals*
  - *(rainy season)*



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

- *1996: Deep-Sea Drilling Project*
  Leg 165
  (Joides Resolution)

  Hughen et al., 1998
  Haug et al. 1998
  (+others)



Cariaco varve chronology and GISP2 ice core
(from Hughen et al., 1998; Nature)

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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*

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Scientific Goals:

Understand linkages between oceanographic processes and the production and sinking flux of particulate matter

Explain climate / paleoclimate changes in the region

(Dave Hollander and Laura Lorenzoni collecting Cariaco sediment from a box corer…some people just love playing with mud…)

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Hypotheses

- *The sinking flux of particulate matter contains a decipherable record of event- to interannual-scale variations in upper ocean conditions.*
- *Temporal variability in nutrient availability results in ecosystem shifts that are recorded in the Si:C:N:P ratio and mineral ballasting of sinking particulates.*
- *Temporal changes in the intensity and frequency of intrusions, which ventilate mid-depth layers, affect bacterial communities and the sinking material flux.*
- *Chemoautotrophic bacteria near the oxic-anoxic transition zone alter the composition of the vertical particulate flux and the dissolved organic matter concentration, and contribute to the carbon flux.*

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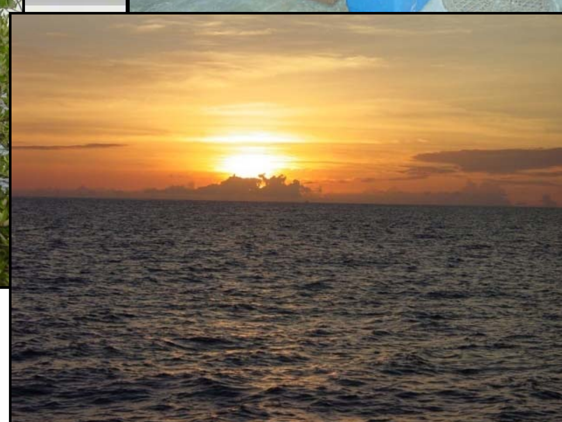
Operational Objectives

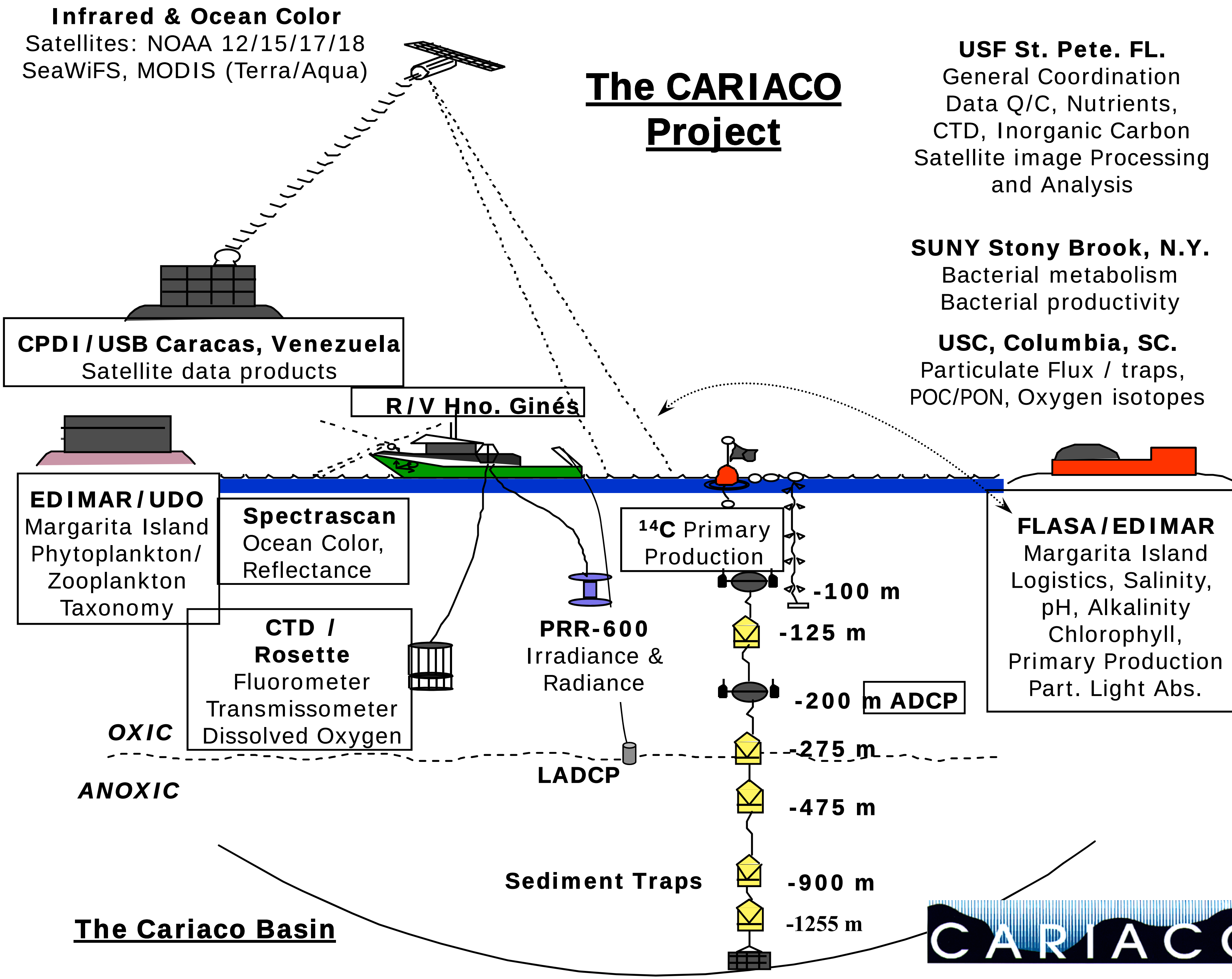
- *Collect a time series of observations*
- *Establish a community facility*
- *Outreach, capacity building*
- *Improve international linkages*

CARIACO Logistics and Operations

Estación de Investigaciones Marinas de Margarita
EDIMAR

Tropical research station




Infrared & Ocean Color
Satellites: NOAA 12/15/17/18
SeaWiFS, MODIS (Terra/Aqua)
The CARIACO Project
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
14C Primary
Production
FLASA / EDIMAR
Margarita Island
Logistics, Salinity,
pH, Alkalinity
Chlorophyll,
Primary Production
Part. Light Abs.
CTD / Rosette
Fluorometer
Transmissometer
Dissolved Oxygen
PRR-600
Irradiance &
Radiance
-100 m
-125 m
-200 m ADCP
-275 m
-475 m
-900 m
-1255 m
OXIC
ANOXIC
LADCP
Sediment Traps
The Cariaco Basin
CARIACO

R/V Hermano Gines

25 m (~80 ft)
116 metric Ton
13 crew
8 science party
~$4,000/day

CARIACO

Loading the CTD and rosette

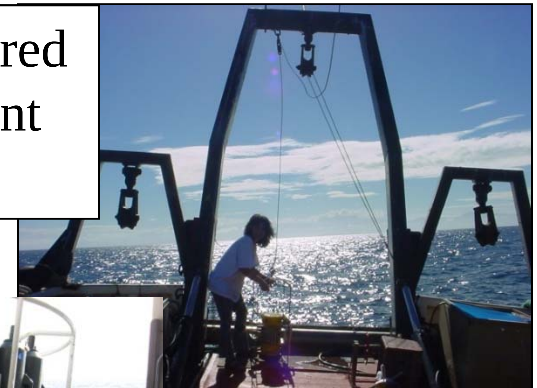
What a team!

Meteorological station

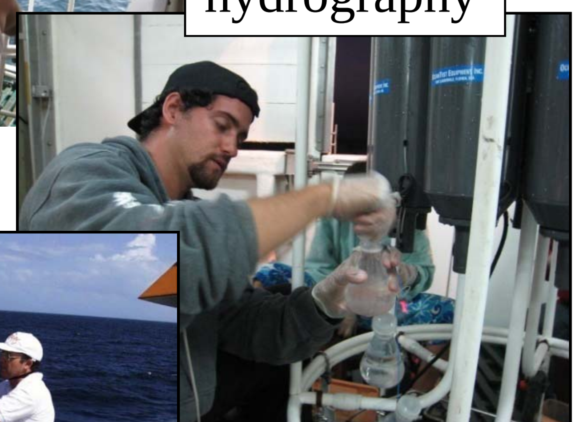
Sampling and keeping records…since November 1995

Filtering…filtering…24 h a day…

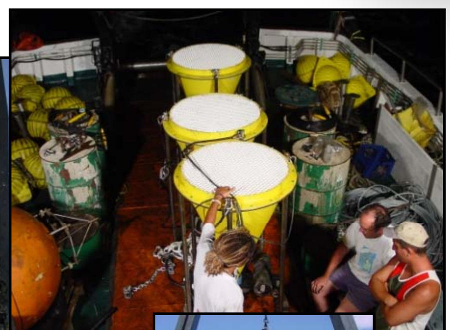
Yrene Astor Keeps us in line



Lowered Current meter



CTD/rosette hydrography



Sediment traps

Zooplankton

Primary productivity

Bio-optics (ocean color)

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Core Time Series Observations

Chemical,
Biological,
Geological,
Physical

Parameter	Depth Range	Instrument/Method	Frequency and last year for which data are available
1. Continuous Parameters			
Pressure (Depth)	0-1310 m	SBE-25 (SeaBird)	Monthly, 2007
Temperature	0-1310 m	SBE-25 (SeaBird)	Monthly, 2007
Conductivity (Salinity)	0-1310 m	SBE-25 (SeaBird)	Monthly, 2007
Dissolved Oxygen	0-1310 m	SBE-43 (SeaBird)	Monthly, 2007
Fluorescence (Chl)	0-1310	Fluorometer	Monthly, 2007
Beam attenuation (c660)	0-1310	C-Star (WetLabs)	Monthly, 2007
2. Water Column Chemical/Biological Measurements (Depths: 1, 7, 15, 25, 35, 55, 75, 100, 200, 225, 250, 300, 350, 400, 500, 750, 1310)			
Dissolved Oxygen	0-1310 m	Titration	Monthly, 2007
DOC & TOC	0-1310 m	High Temp Comb	Monthly, 2006
Total Alkalinity	0-1310 m	Titration	Monthly, 2007
pH	0-1310 m	Spectrophotometer	Monthly, 2007
Salinity	0-1310 m	Guildline Portasal 8410	Monthly, 2007
Nitrate	0-1310 m	Autoanalyzer	Monthly, 2006
Nitrite	0-1310 m	Autoanalyzer	Monthly, 2006
Ammonia	0-1310 m	Autoanalyzer	Monthly, 2006
Phosphorus	0-1310 m	Autoanalyzer	Monthly, 2006
Silicate	0-1310 m	Autoanalyzer	Monthly, 2006
Diss. Org. Nitrogen	0-1310 m	Persulfate oxidation	Monthly, 2006
Diss. Org. Phosphorous	0-1310 m	Persulfate oxidation	Monthly, 2006
Partic. Organic Carbon	0-1310 m	High Temp Comb	Monthly, 2006
Total (org.) Partic. N, P	0-1310 m	High Temp Comb	Monthly, 2006
Chl., other pigments, taxonomy	0-100 m	Fluorometry, HPLC, microscope counts	Monthly, 2007
Bacteria	0-1310 m	(Various/Stony Brook U.)	Monthly, 2006
Viruses and Protozoa	0-1310 m	(Various/ Stony Brook U.)	Infrequent; 2006
3. Carbon Assimilation and Particle Flux			
Primary Production, chemoautotrophy	0-100 m	^{14}C (Various/USF, FLASA, Stony Brook U.)	Monthly, 2007 (chemo.: twice/year)
Bacterial Product., Resp.	0-1310 m	(Various/ Stony Brook U.)	Twice/year; 2006
Fe, Mn, S (H_2S, $S_2O_3^=$. $SO_3^=$, S^0), CH_4	0-1310 m	(Various/ Stony Brook U.)	Twice/year; 2006
4. Optical Measurements			
Incident Irradiance	Surface	Spectrascan	Monthly, 2007
Upwelling Radiance and Downwelling Irradiance	0-150 m	PRR-600	Monthly, 2007
Satellite imagery	Surface	Color/IR, various satellites	Daily; 2007
5. Moored Instruments			
Sediment Traps (C, N, P, $CaCO_3$, SiO_2, stable isotopes, etc.)	150, 230, 410, 810, 1200 m	Automated sediment traps (U. South Carolina)	Biweekly integrations; 2007
Acoustic Doppler Current Profiler (ADCP)	<500 m	ADCP (RDI)	10 minutes; year-long records; 2006
Lowered ADCP	1-1300 m	WH Sentinel 300 (RDI)	Monthly, 2007

CARIACO cruises and data policy

Since Nov 1995:
172 core cruises (September 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/

CARIACO

Publications

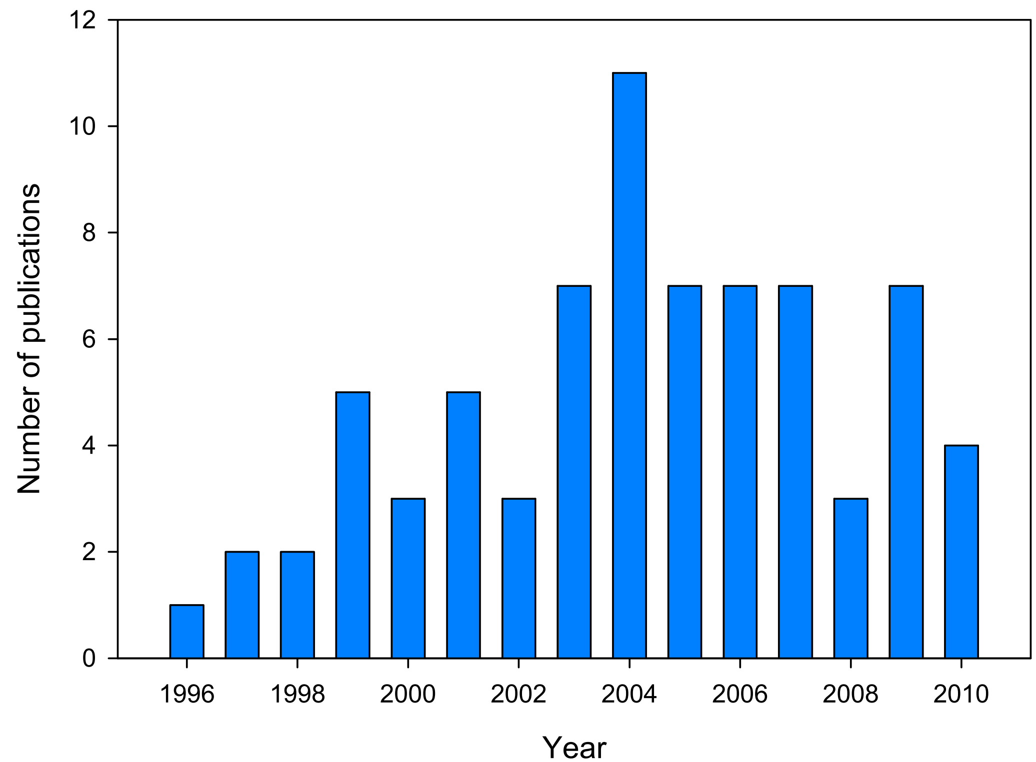
Budget:
~ $0.8M /year NSF
~ $0.2M /year Venezuela

~75 peer reviewed publications through 2010

Over 230 people participated between 2000 and 2010

US: >85 scientists, students, technicians

Venezuelan: >155 scientists, students, technicians



CARIACO AS A COMMUNITY FACILITY

Served as project platform to over 20 national and international institutions, including:

Universidad Simon Bolivar (Venezuela), Universidad Central de Venezuela (Venezuela), Universidad de Oriente (Venezuela), IVIC (Venezuela), University of South Carolina (USA), University of South Florida (USA), SUNY (USA), University of Louisiana (USA), Northeastern University (USA), WHOI (USA), University of California, Irwin (USA), University of California, Riverside (USA), University of Massachusetts (USA), University of Miami (USA), IFM-GEOMAR (Germany), Institut de Ciencies del Mar (Spain), NIOZ (The Netherlands), Columbia University LDEO (USA), Skidaway Institute of Oceanography (USA), Boston University (USA), Oregon State University (USA), University of Rhode Island (USA),

Fundación Instituto de Ingeniería (Venezuela).

Time… the long and the short…

RESULTS

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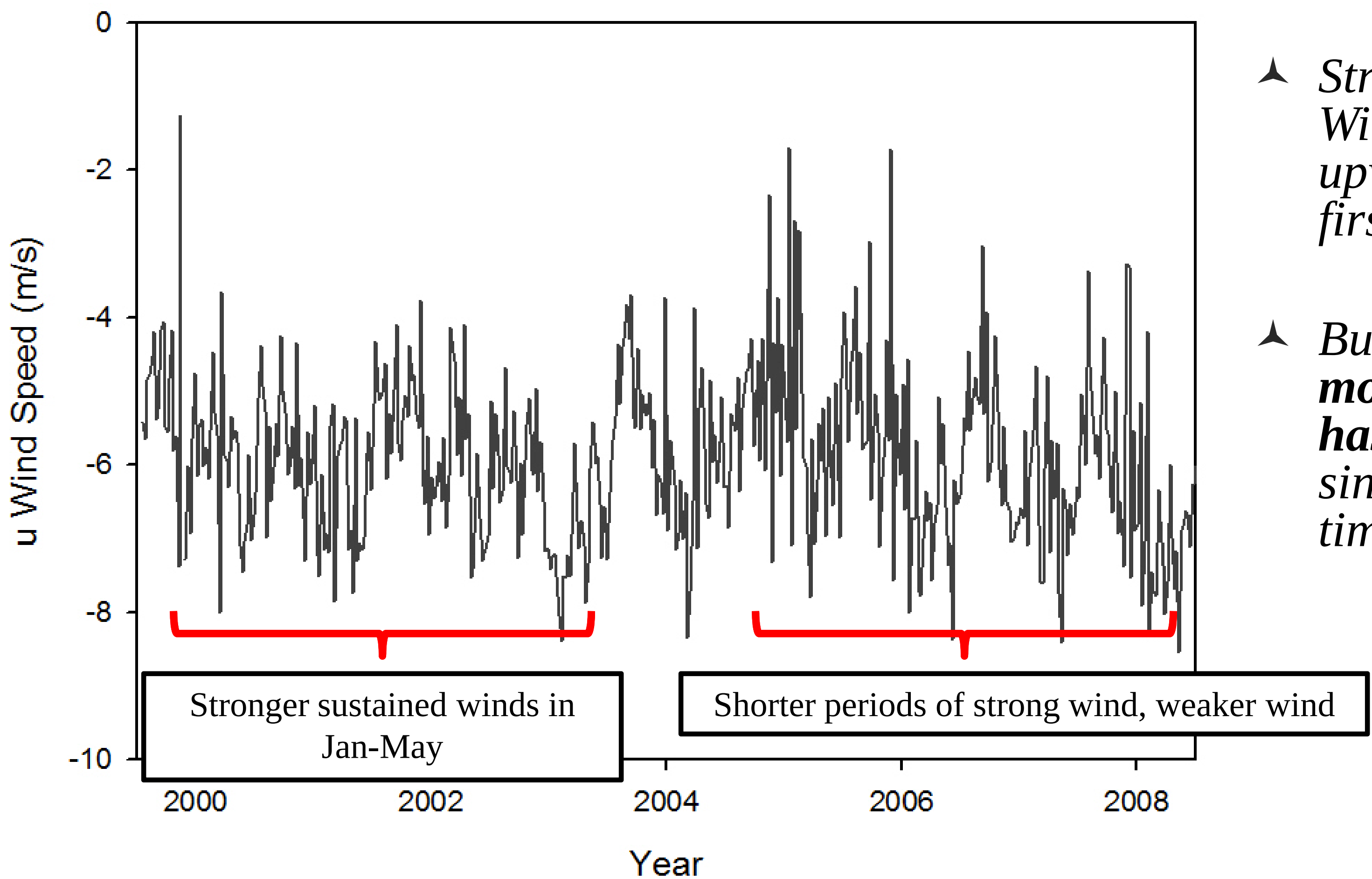
East-west wind in southern Caribbean

from QuikScat satellite



- *Stronger Trade Winds induce upwelling during first half of year*
- *But* ***Trade Wind is more variable and has decreased*** *since starting of time series*

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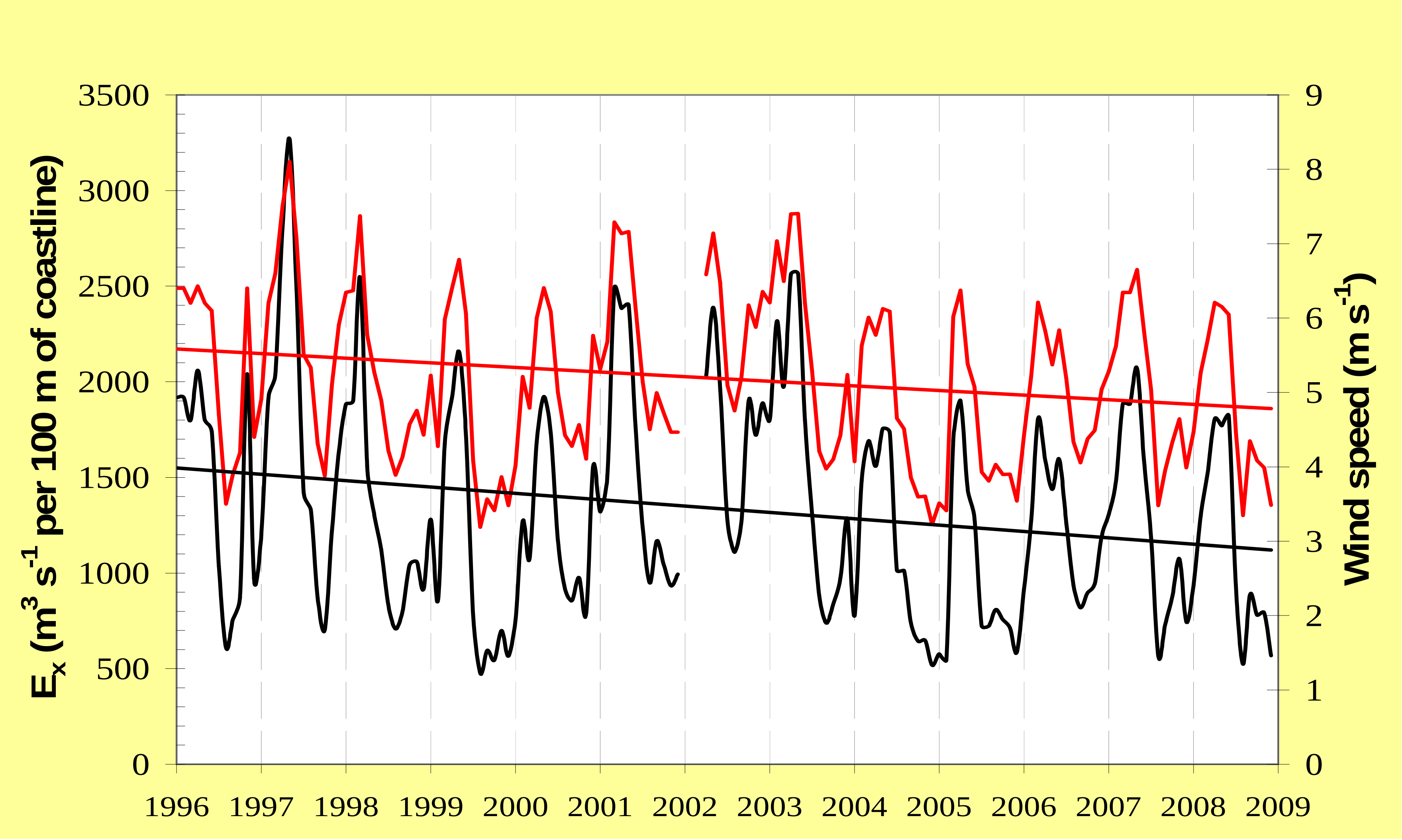
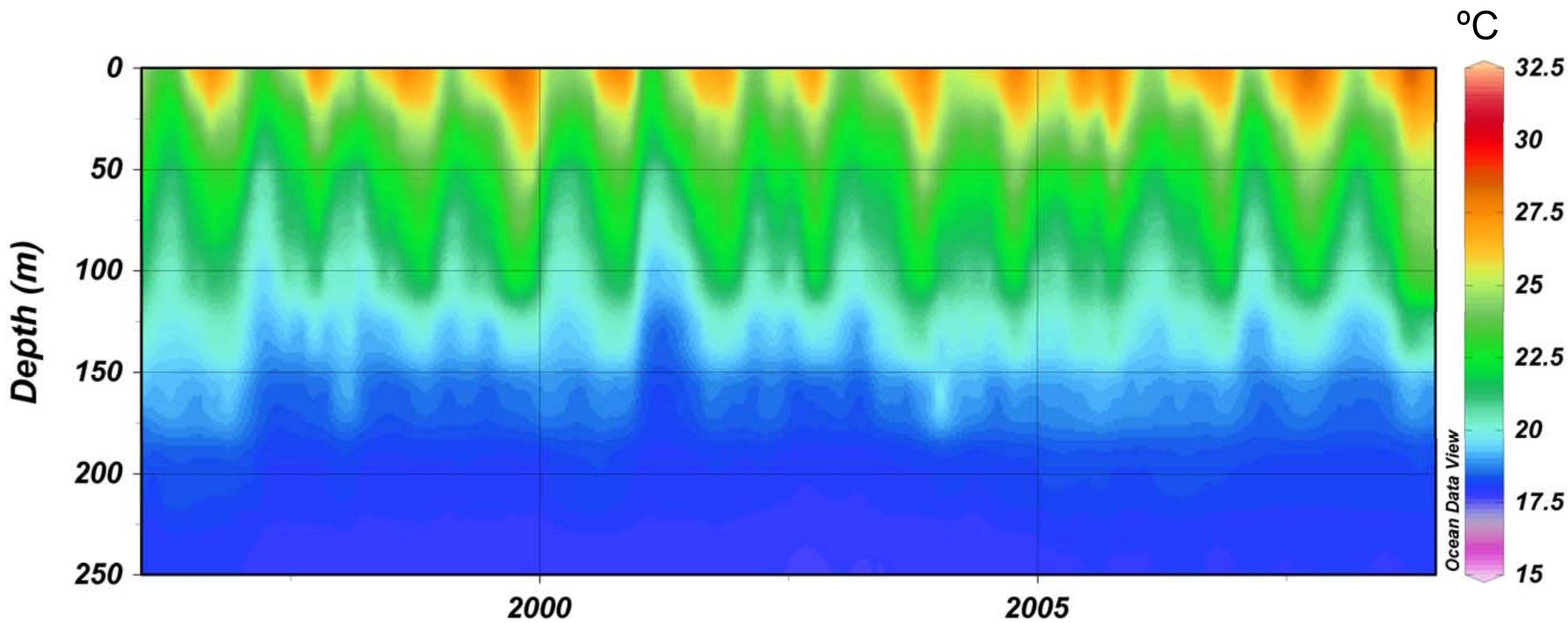
FUNDACIÓN LA SALLE de Ciencias Naturales

Interannual variation in upwelling intensity
Wind speed decrease: -0.05 ± 0.02 m s^{-1} per year

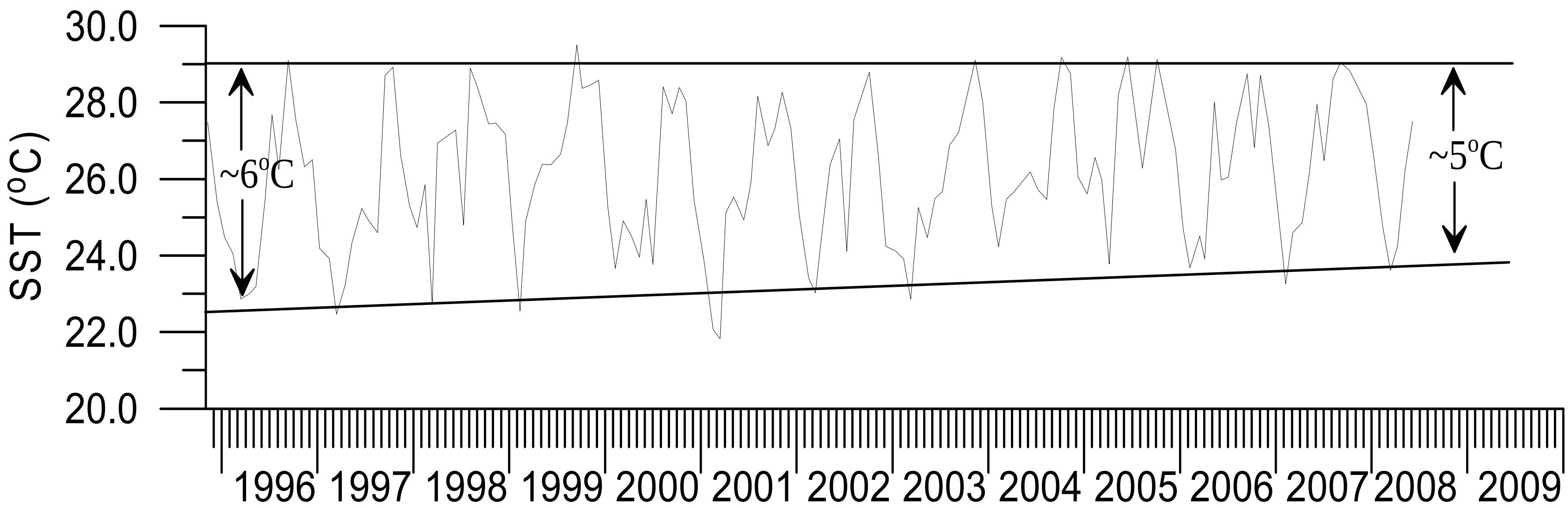


Temperature



Upwelling intensity has decreased since we started the series – Warm-water intervals are longer

Long Term Changes in SST: Reduction in Annual Range

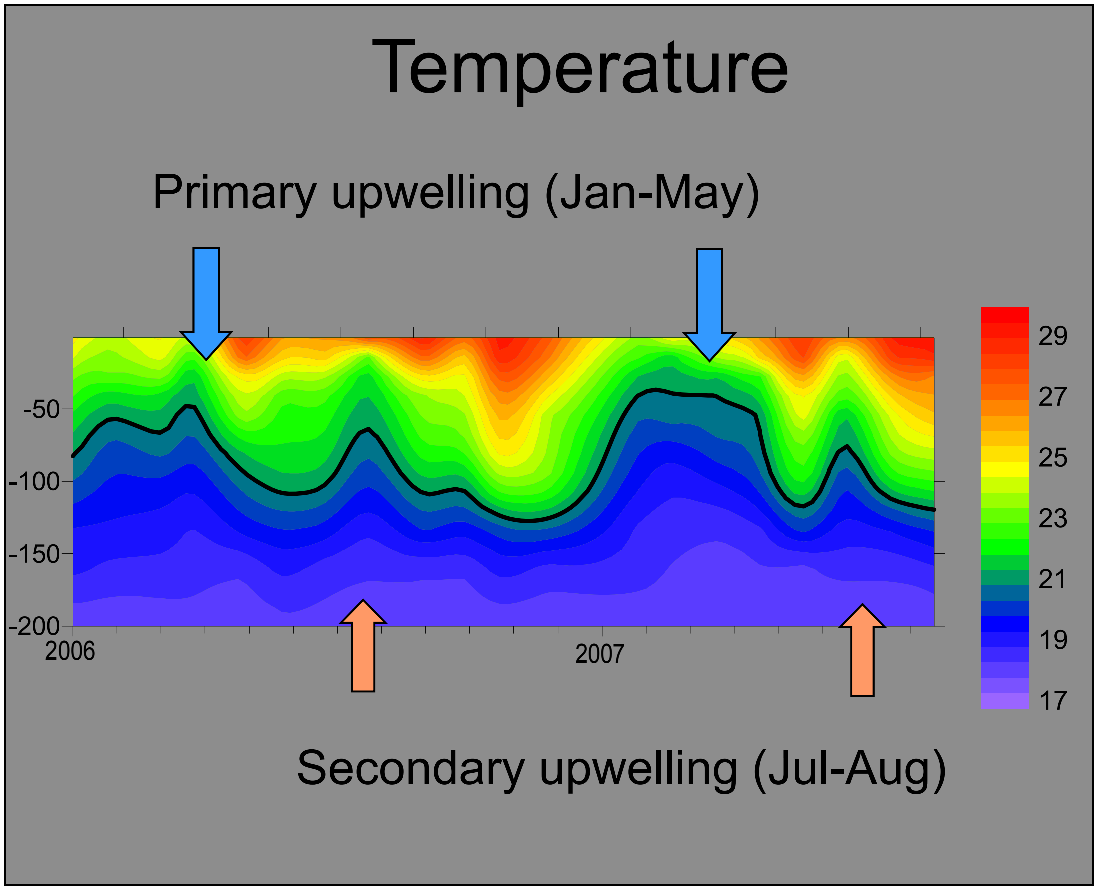


Contributed by
R. Thunell, USC

Secondary upwelling: discovered/confirmed only after about 12 years of data!

- *Cariaco Basin experiences a secondary upwelling event in "summer"*

(Work of Digna Rueda)



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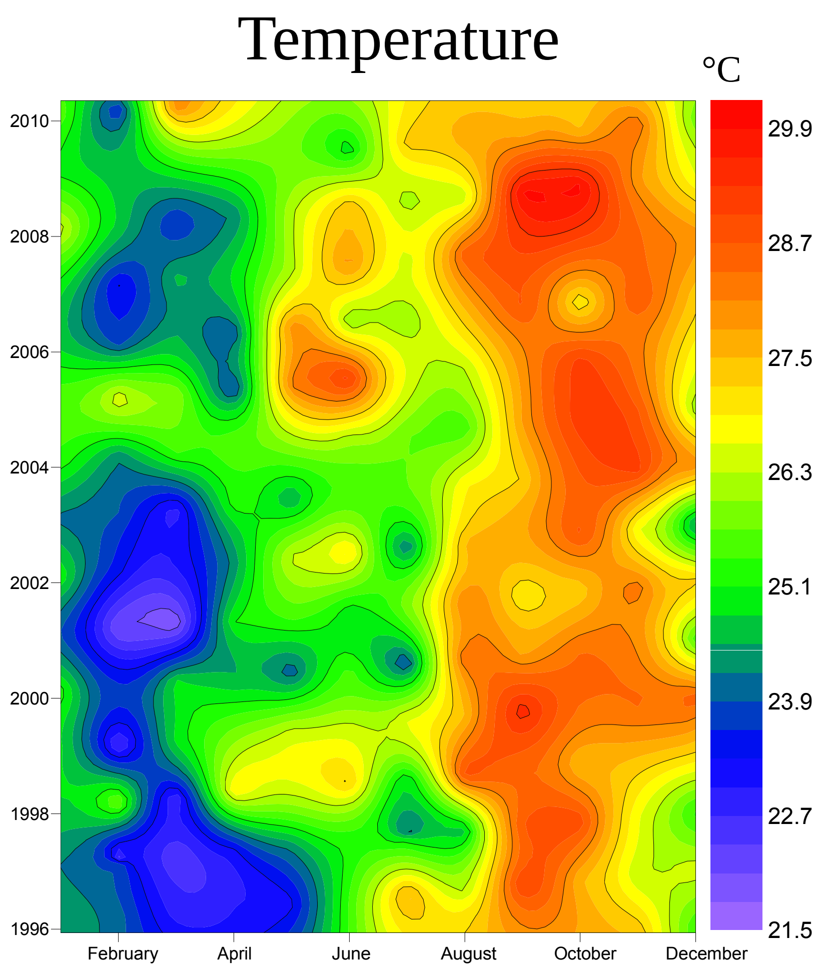
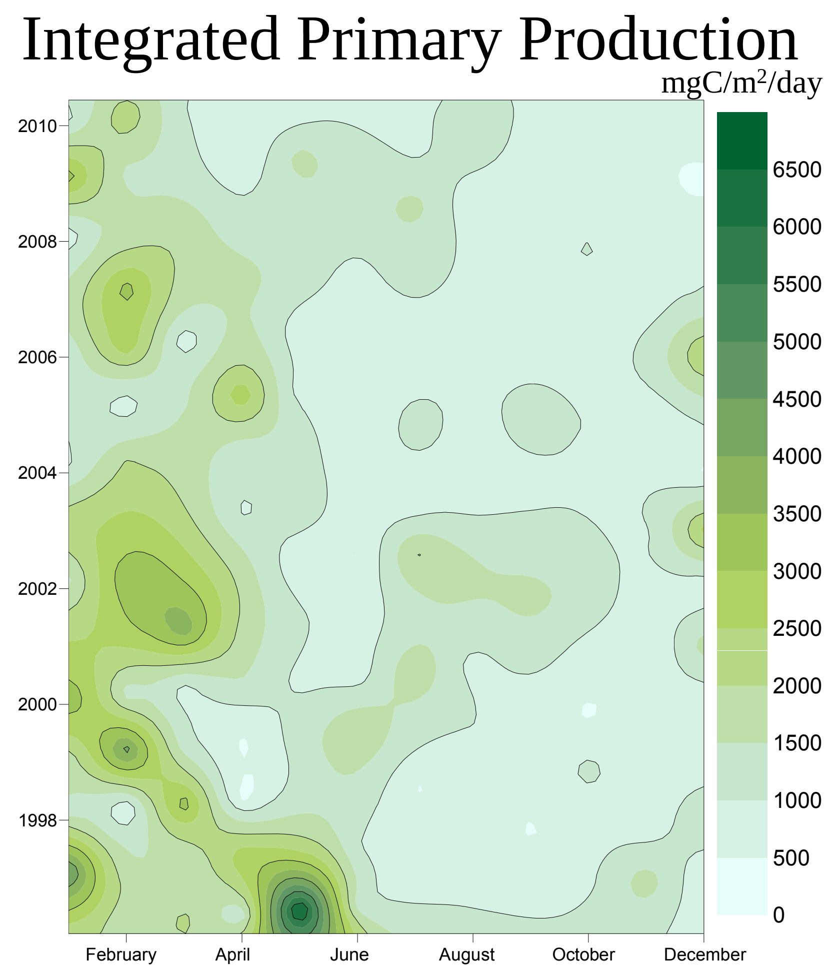
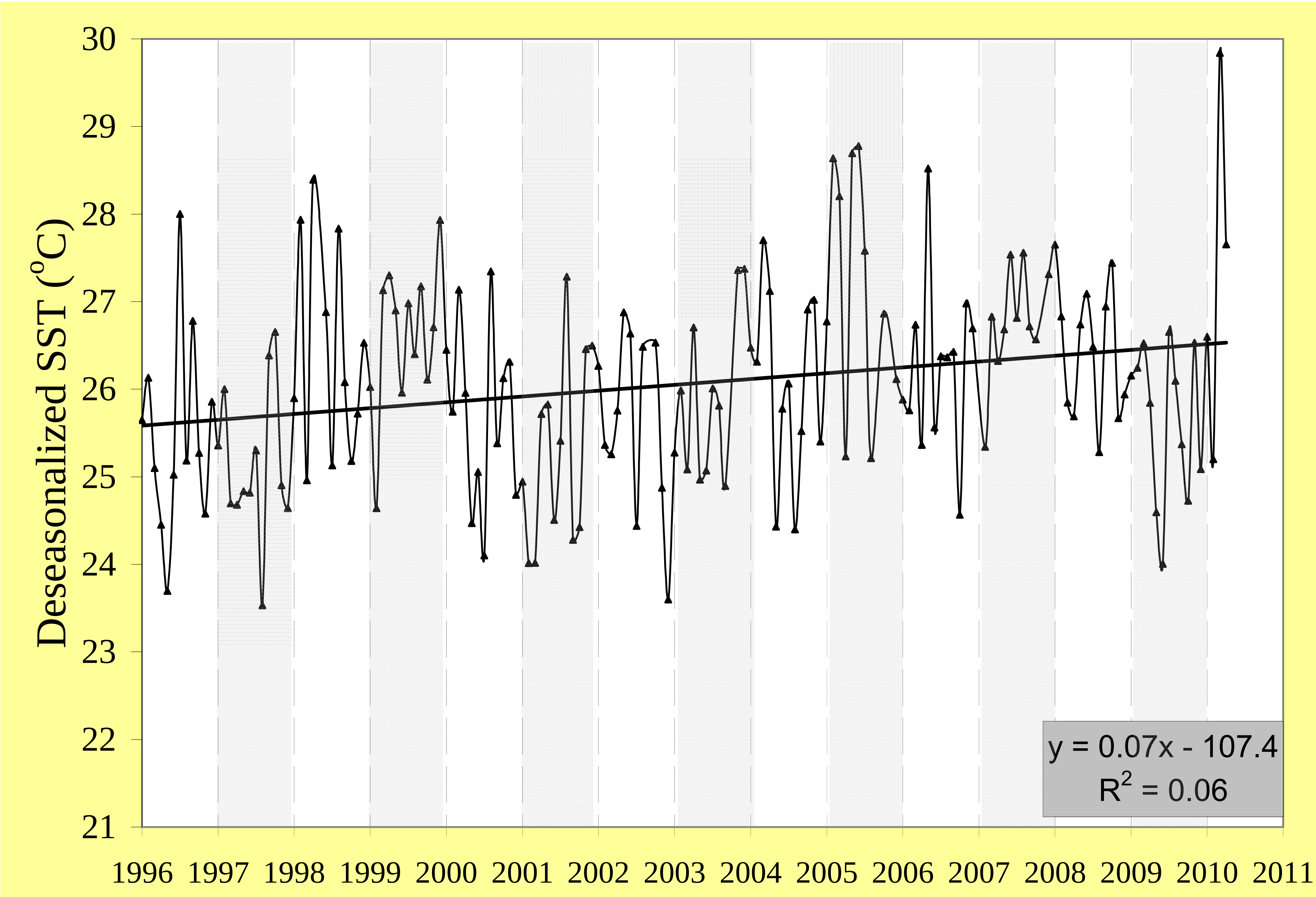
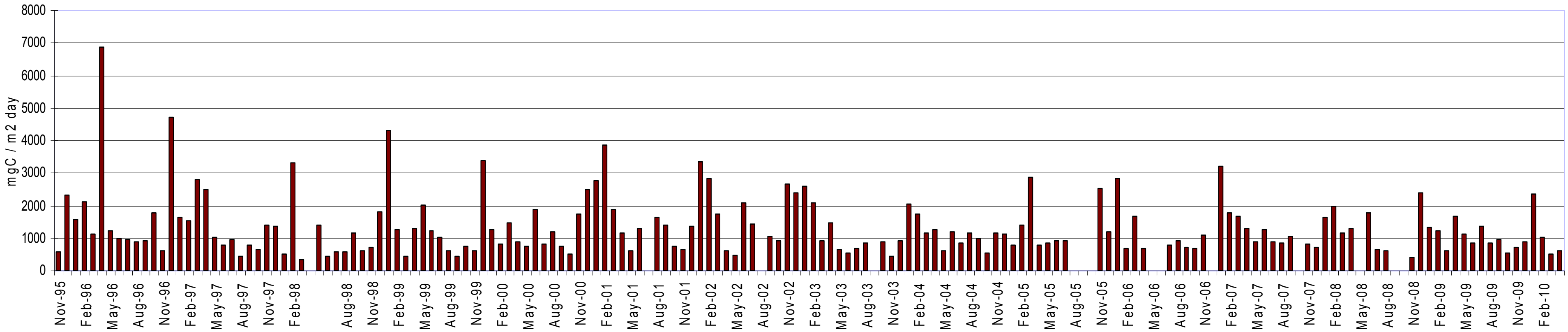




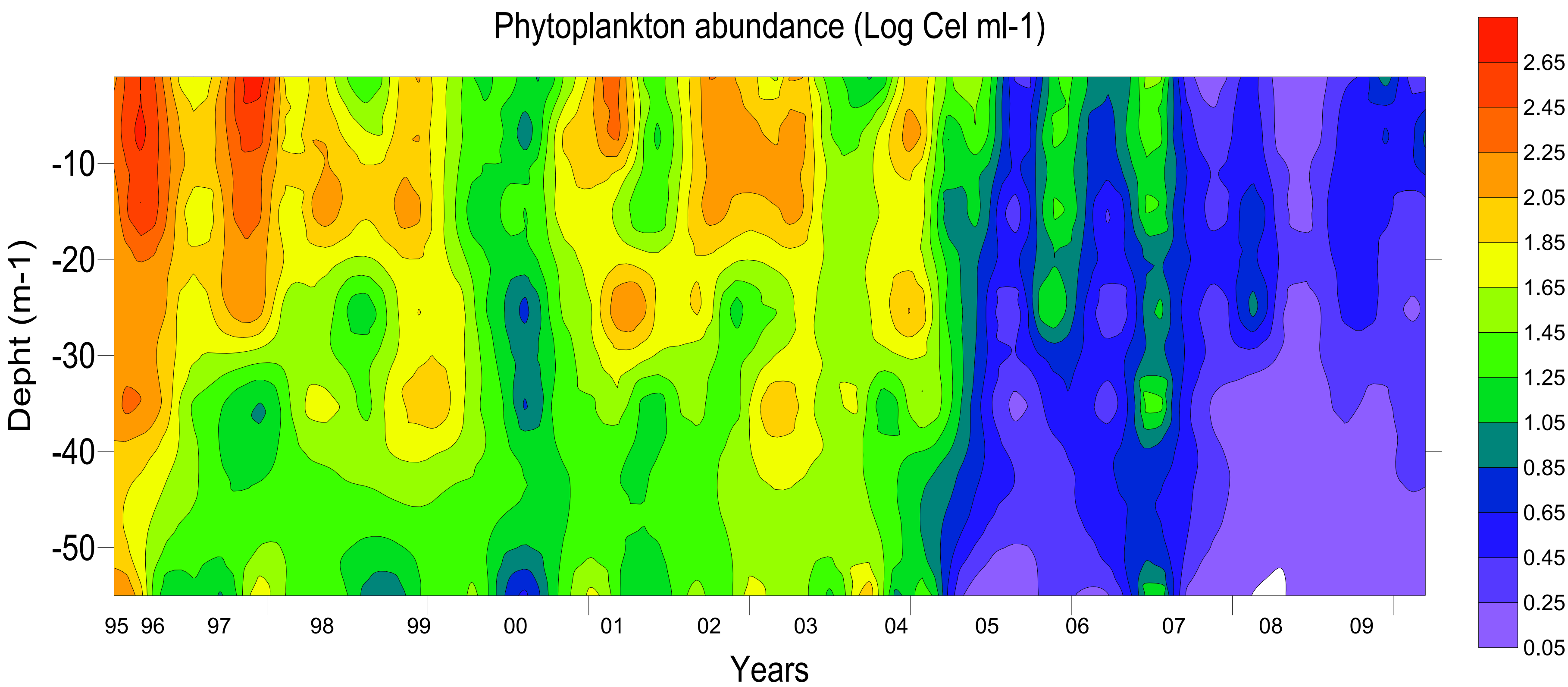
- *Chlorophyll and primary production highest in Jan-Apr*
- *Secondary summer upwelling PP peak is now weaker*
- *Shift in phytoplankton community since ~2000 (now smaller cells)*

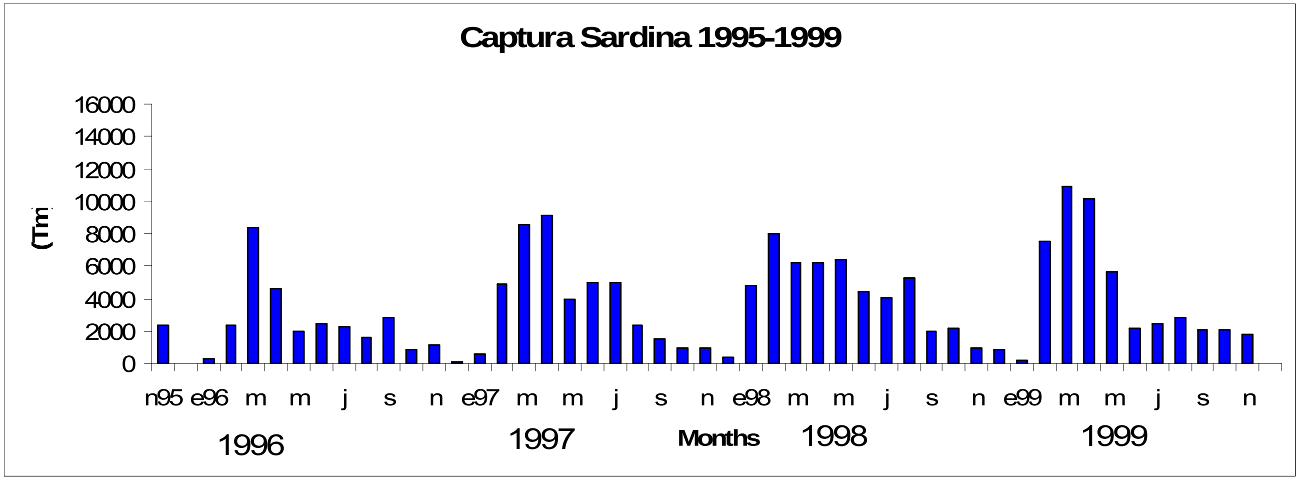

Deseasonalized SST (oC)
30
29
28
27
26
25
24
23
22
21
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
y = 0.07x - 107.4
R2 = 0.06

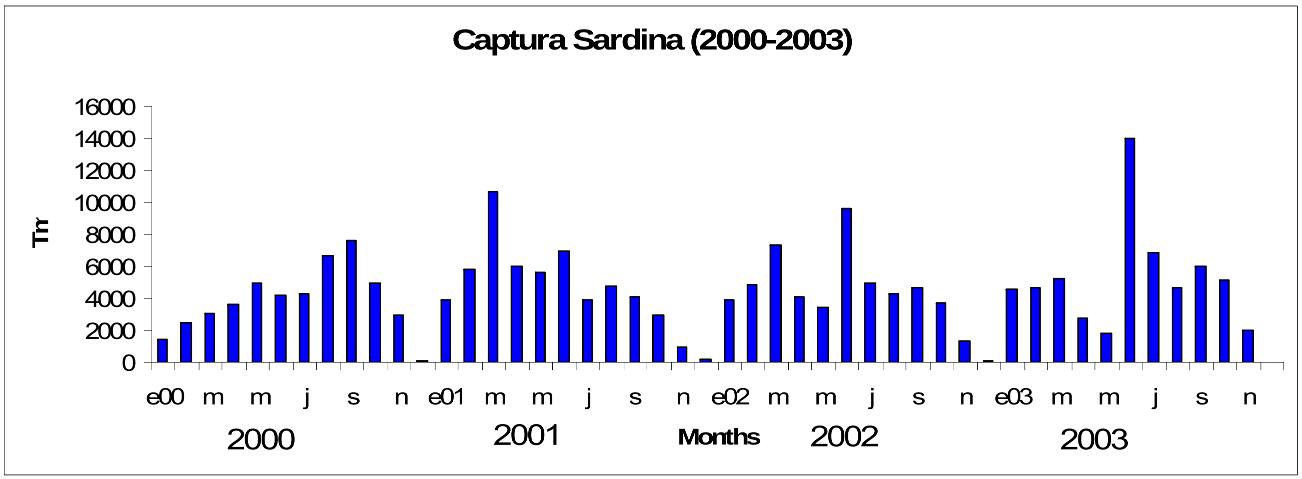
Primary Productivity



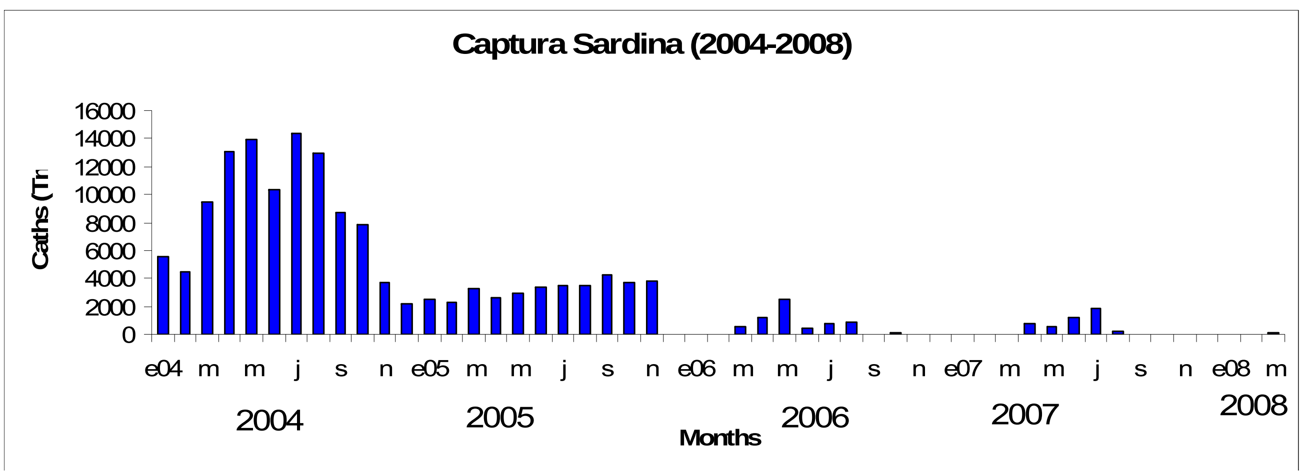
- *Amplitude of PP decreased since ~2000*
- *Total annual production has decreased (from >500 gC/m2/y to ~~400 gC/m2/y)*


Phytoplankton abundance (Log Cel ml-1)
Depht (m-1)
-10
-20
-30
-40
-50
95
96
97
98
99
00
01
02
03
04
05
06
07
08
09
Years
2.65
2.45
2.25
2.05
1.85
1.65
1.45
1.25
1.05
0.85
0.65
0.45
0.25
0.05

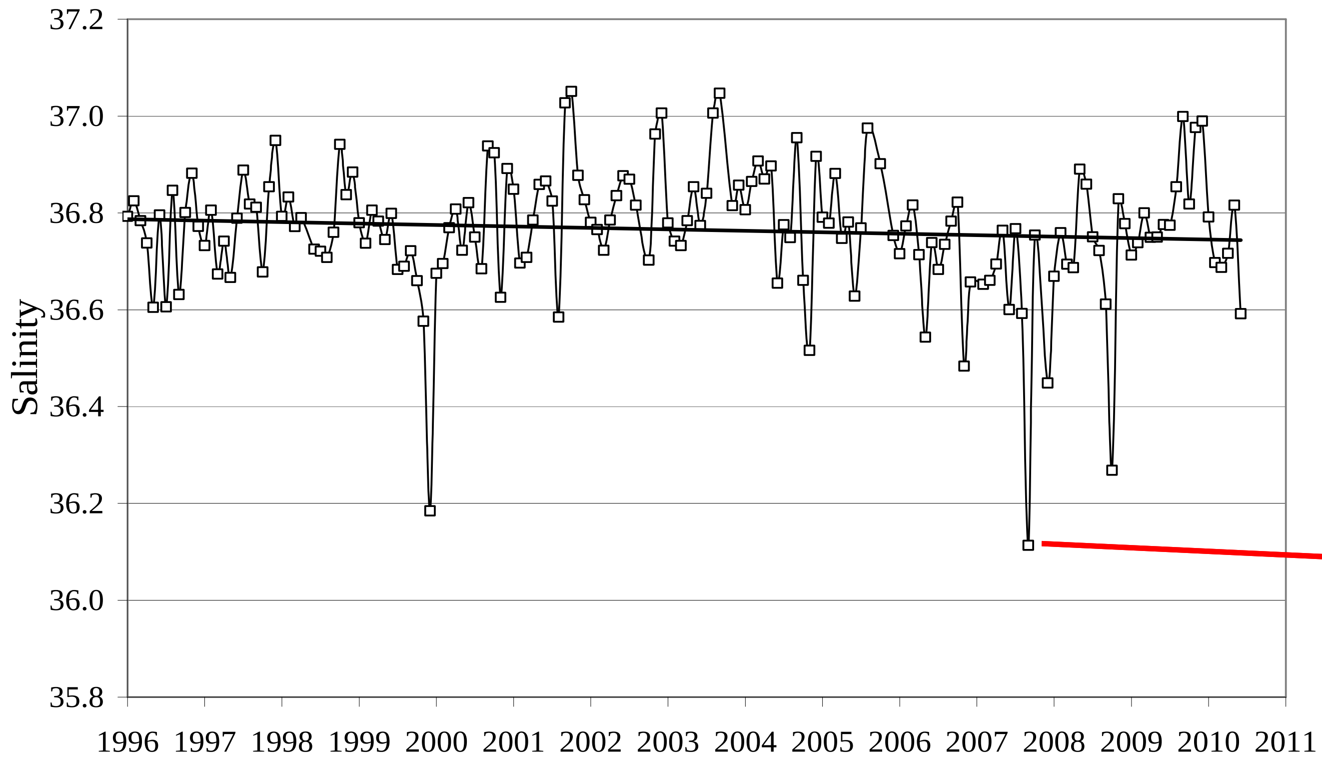




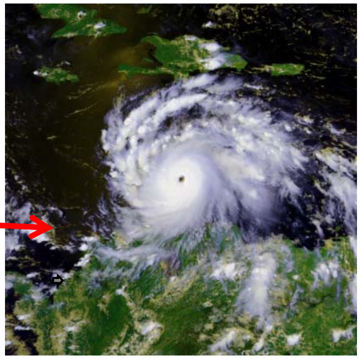
Sardine capture



Trend in salinity:
Larger variations in annual range?

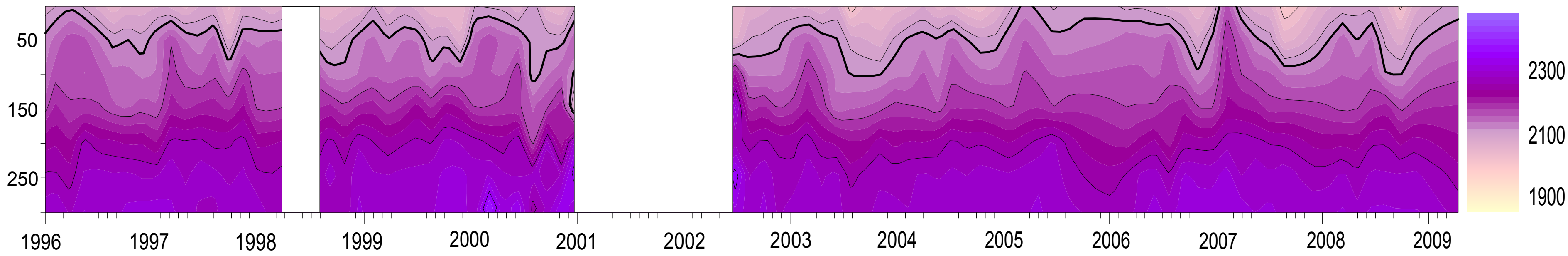


Hurricane Felix



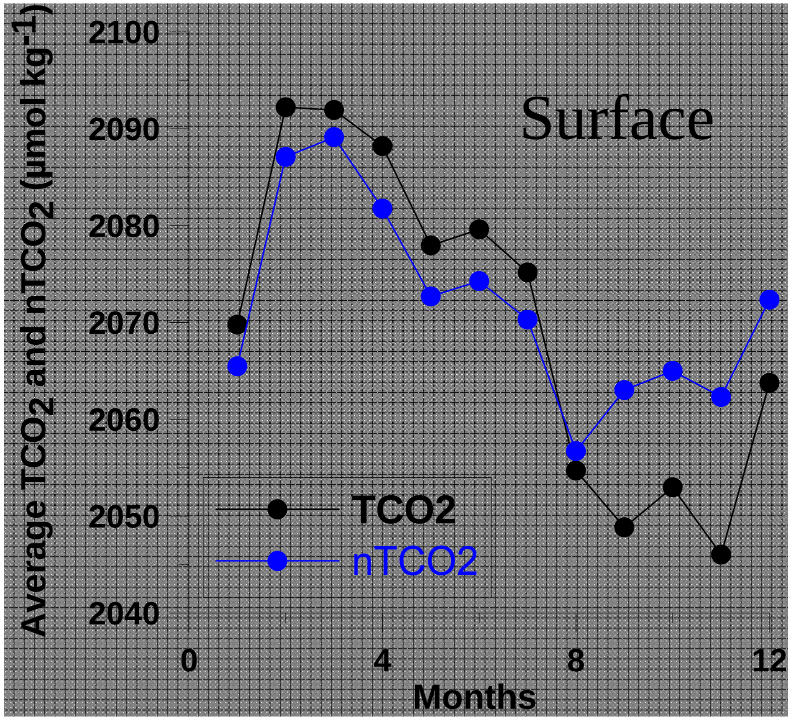
	Temperature	Δ	Salinity	Δ	fCO2	Δ
Max 1996-2001	29.50	**7.68**	37.00	**0.92**	441.70	**143.40**
min 1996-2001	21.82		36.07		298.30	
max 2002-2009	30.00	**7.15**	37.06	**1.22**	452.60	**135.30**
min 2002-2009	22.85		35.84		317.30	

TCO_2 (µmol kg^{-1})



During upwelling, surface values > 2075 µmol kg^{-1}

During non-upwelling, surface values < 2075 µmol kg^{-1}



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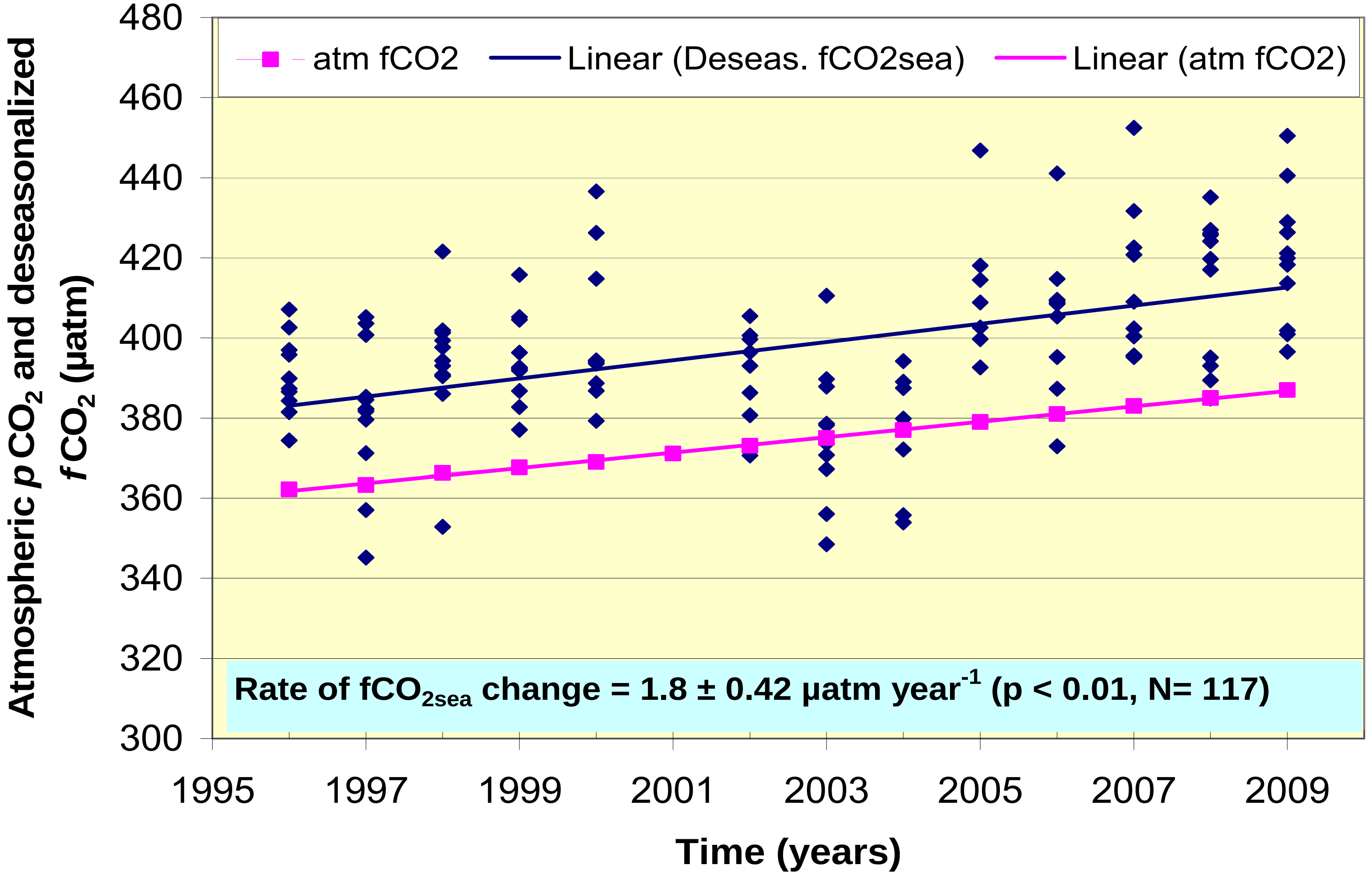
fCO$_2$ (µatm) Deseasonalized values



BaTS, Bates, 2007 / (1.7 ± 0.28 µatm year^{-1})
North Atlantic, Takahashi et al., 2009 (1.8 ± 0.4 µatm year^{-1})

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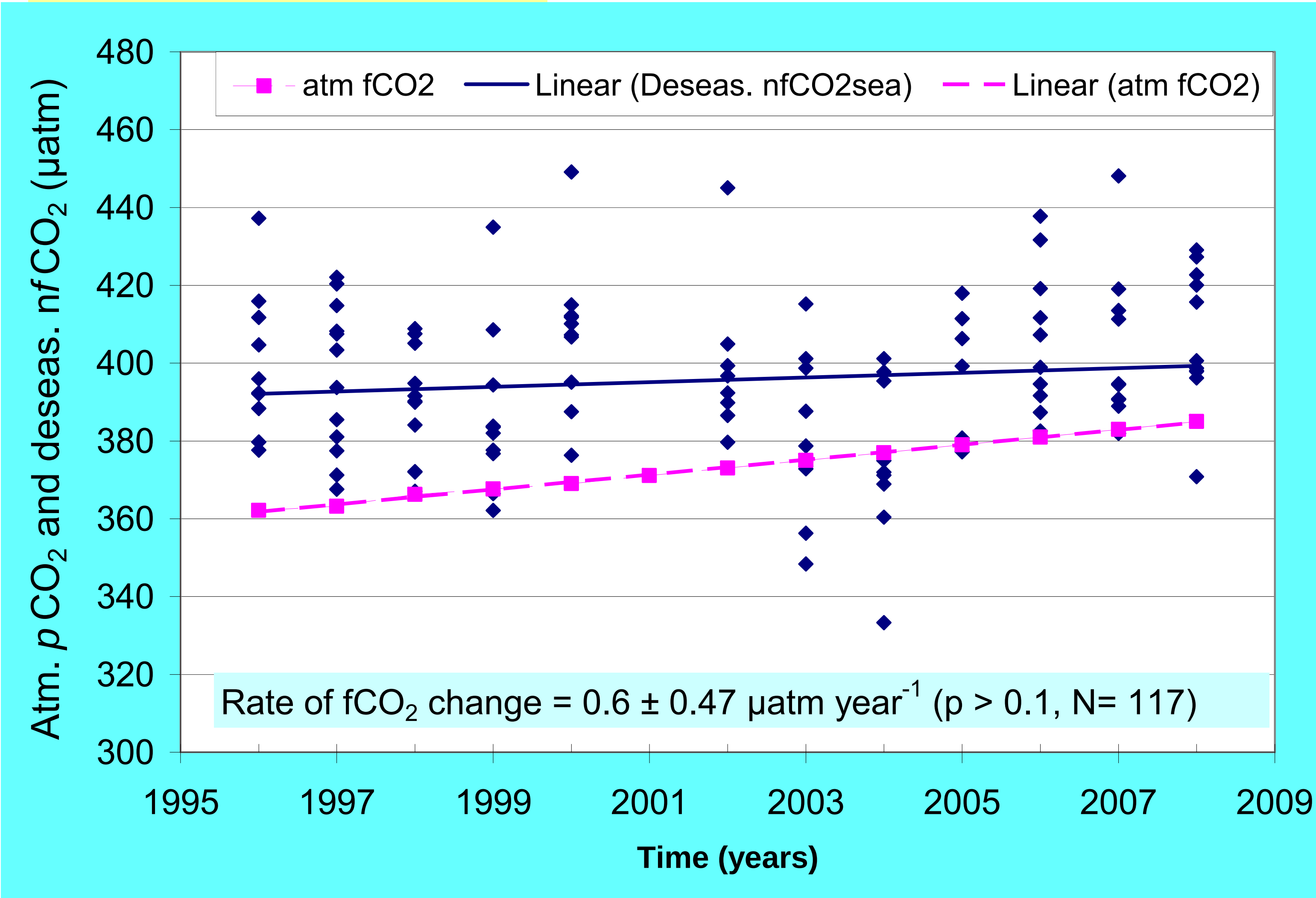
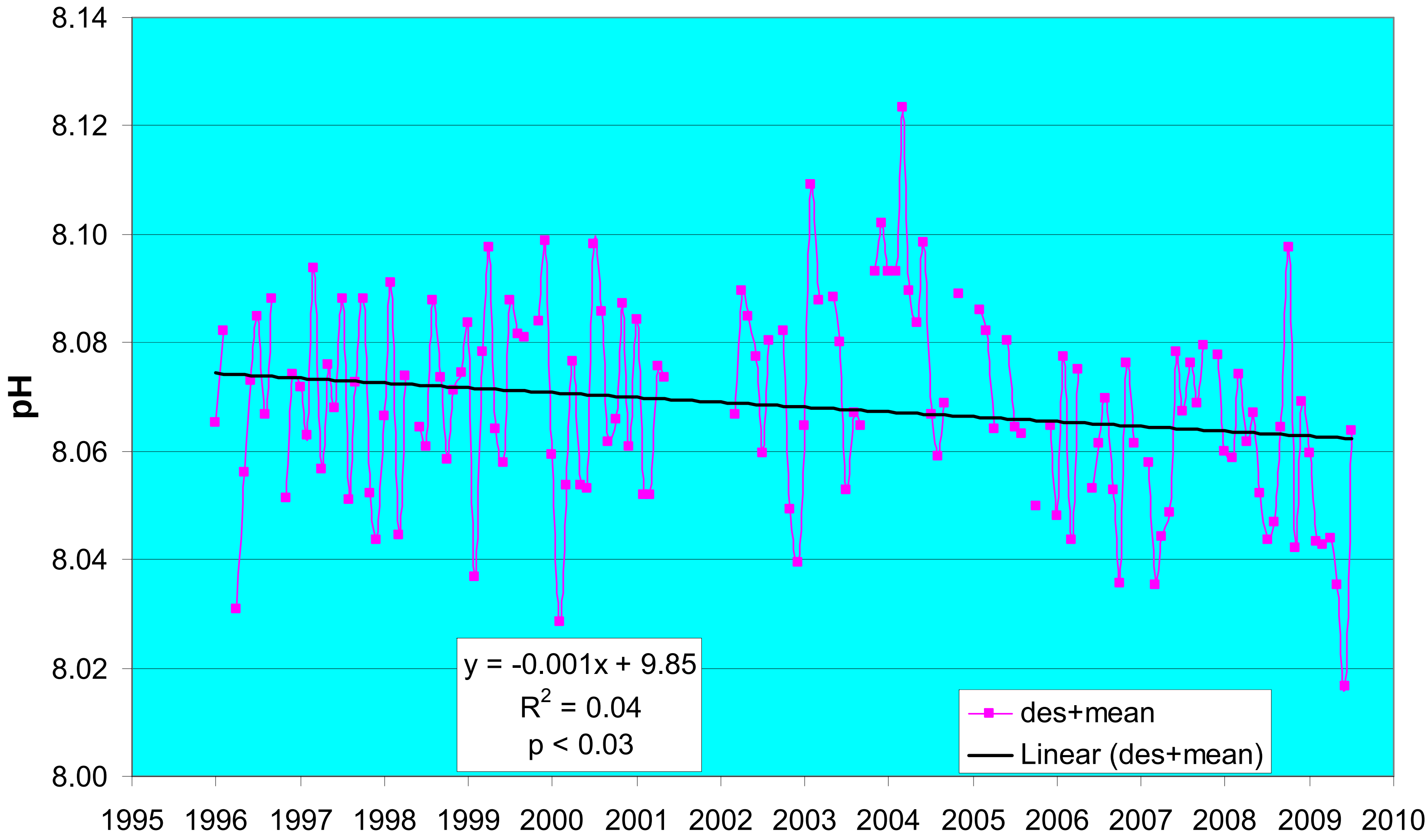
nfCO_2 (µatm)

Deseasonalized values

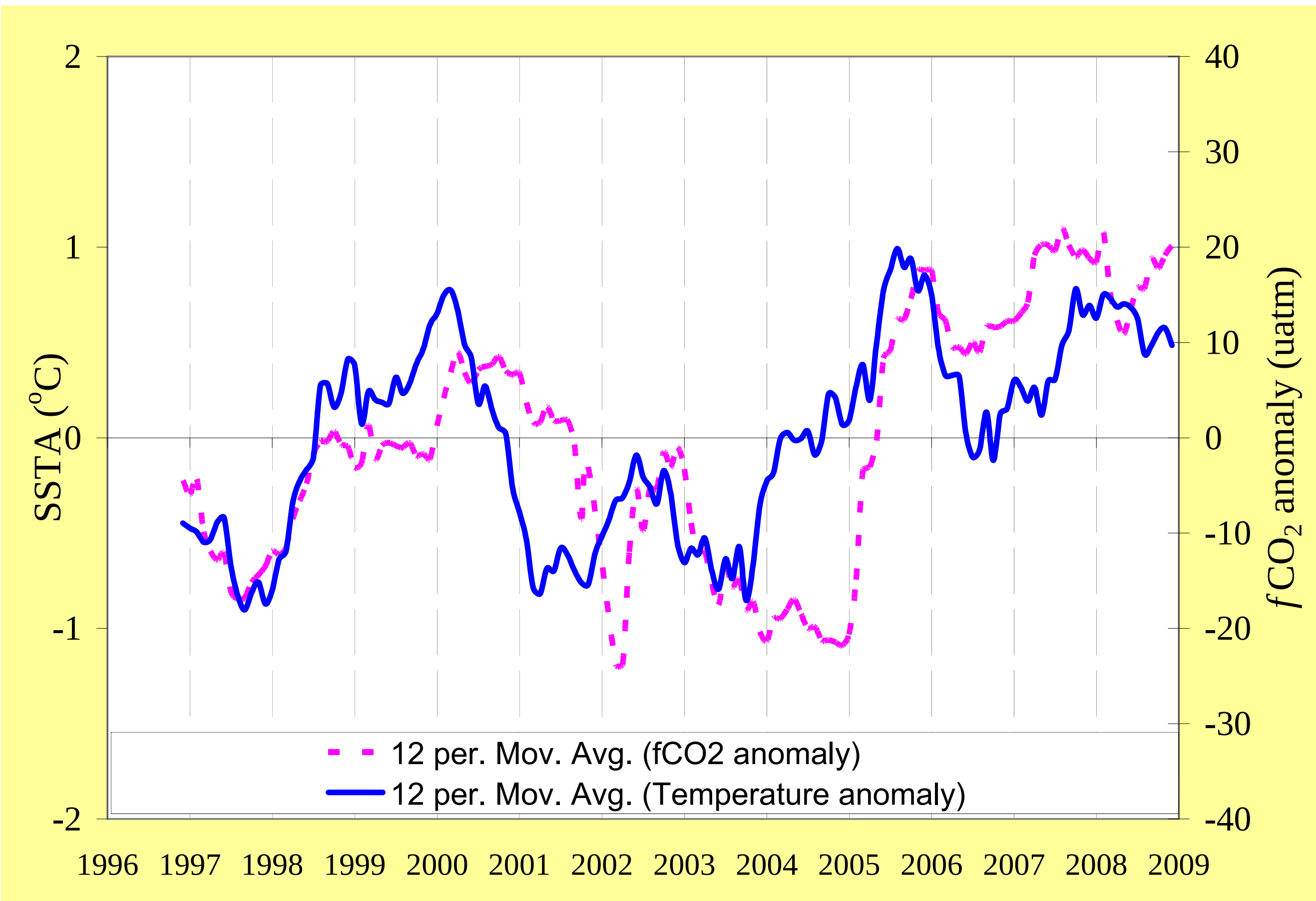


Deseasonalized pH



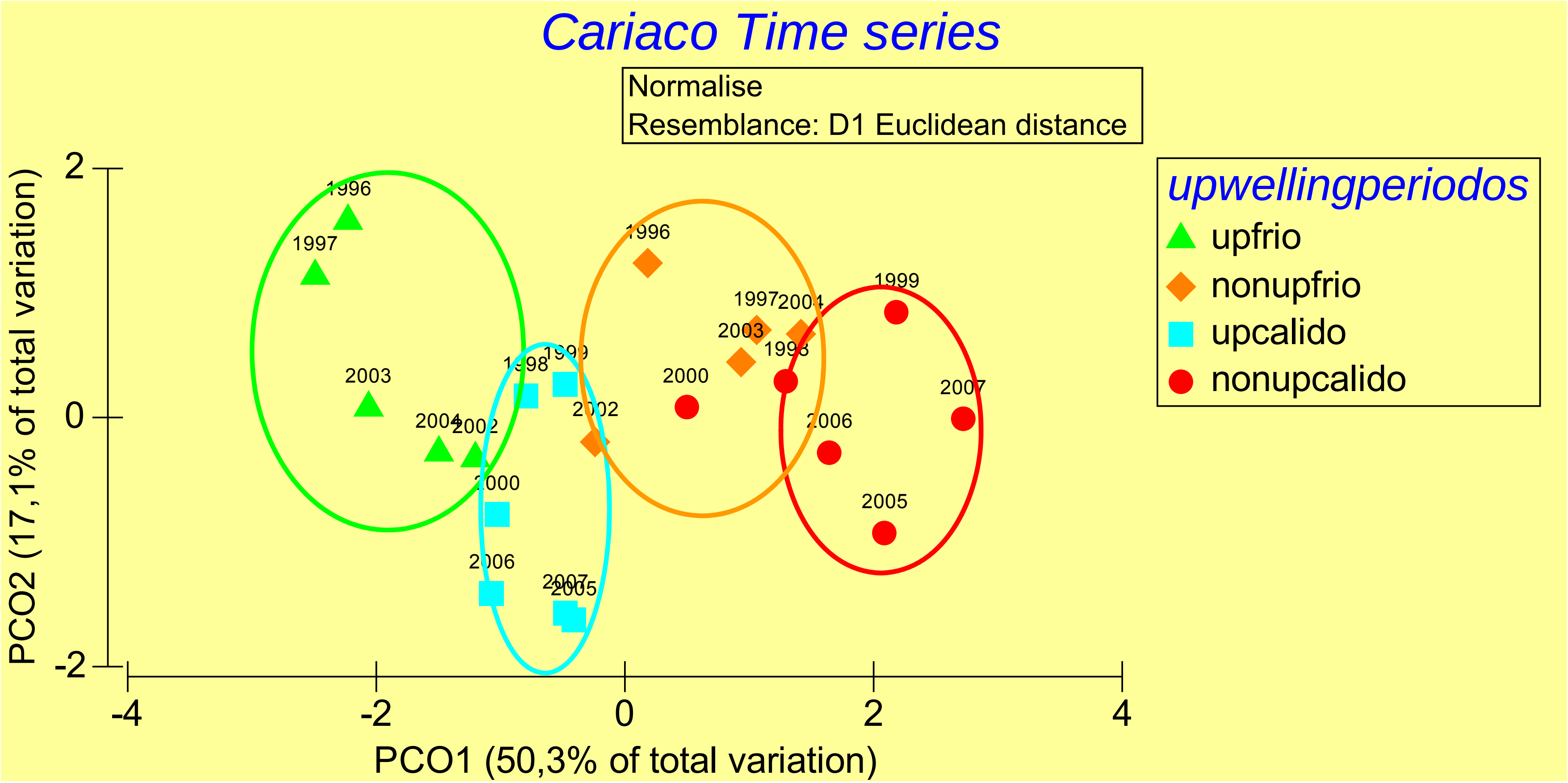
Temperature change drives variations of **4.13-4.23%** *f*CO_{2sea} per 1 °C

Surface heating of 1 °C drives a ~16 µatm increase in *f*CO_{2sea} at CARIACO.



Thermodynamic effects explain **64%** of *f*CO_2 variability

PCO components 1 and 2 explain 67.4 % of the variability



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Phytoplankton productivity has declined,

therefore TCO_2 is not removed,

leading to higher fCO_{2sea}

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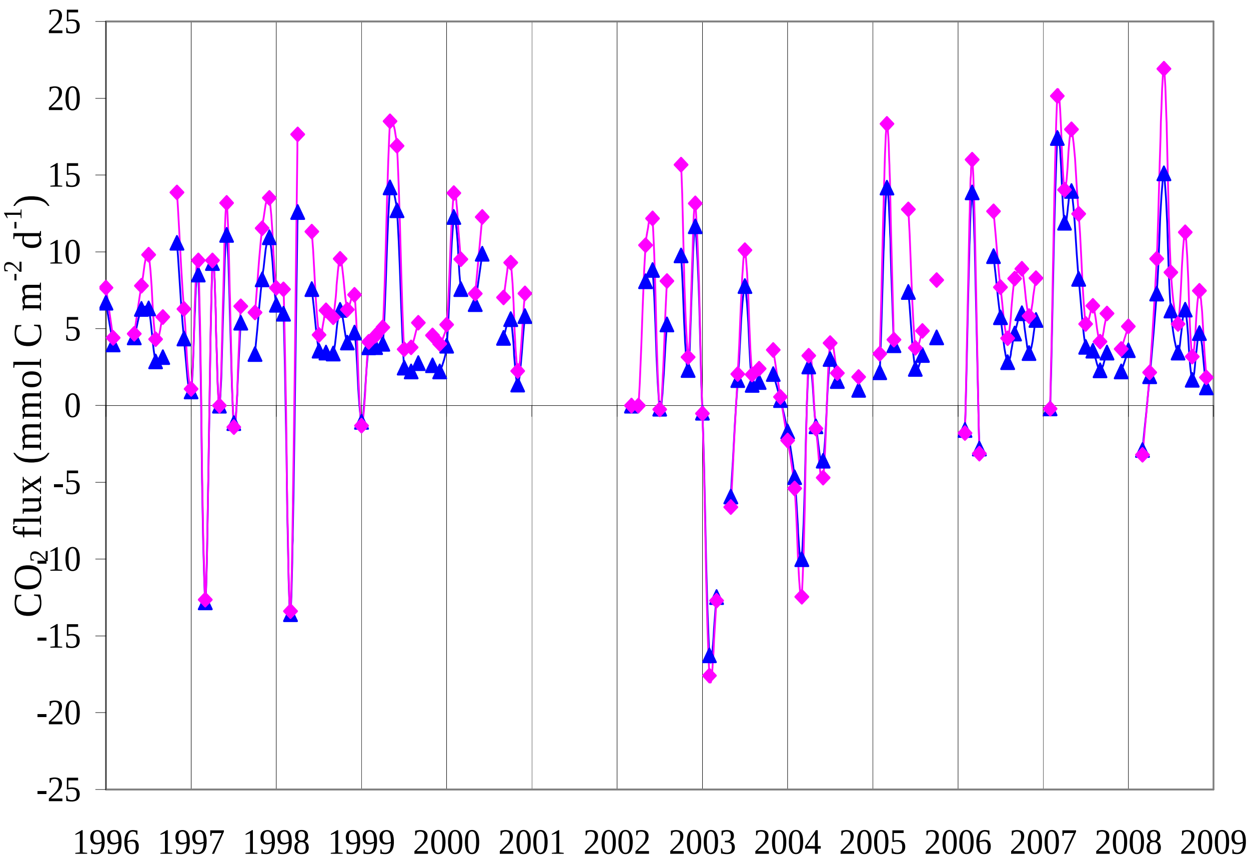
Lower wind speeds (<6 m s^{-1}) and large positive ΔfCO_2 values ($0 < \Delta fCO_{2sea}$ µatm < 60) lead to moderate supersaturation with respect to atmospheric CO_2



Net average (13 years) sea-air CO_2 flux :

1.4 ± 2.1 mol C m^{-2} $year^{-1}$ Wanninkhof parameterization (1992)

2.0 ± 2.5 mol C m^{-2} $year^{-1}$ Nightingale (2000).

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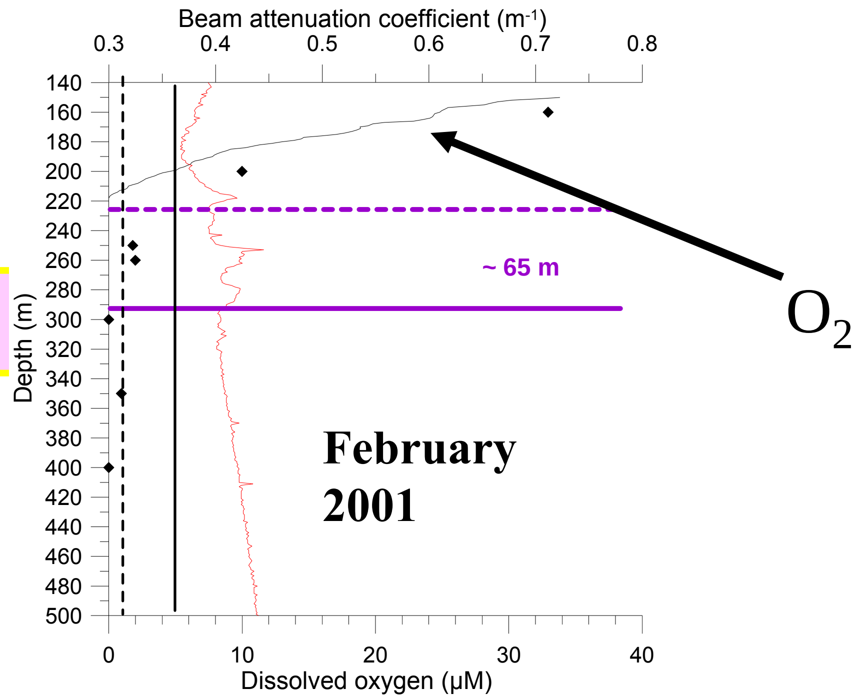
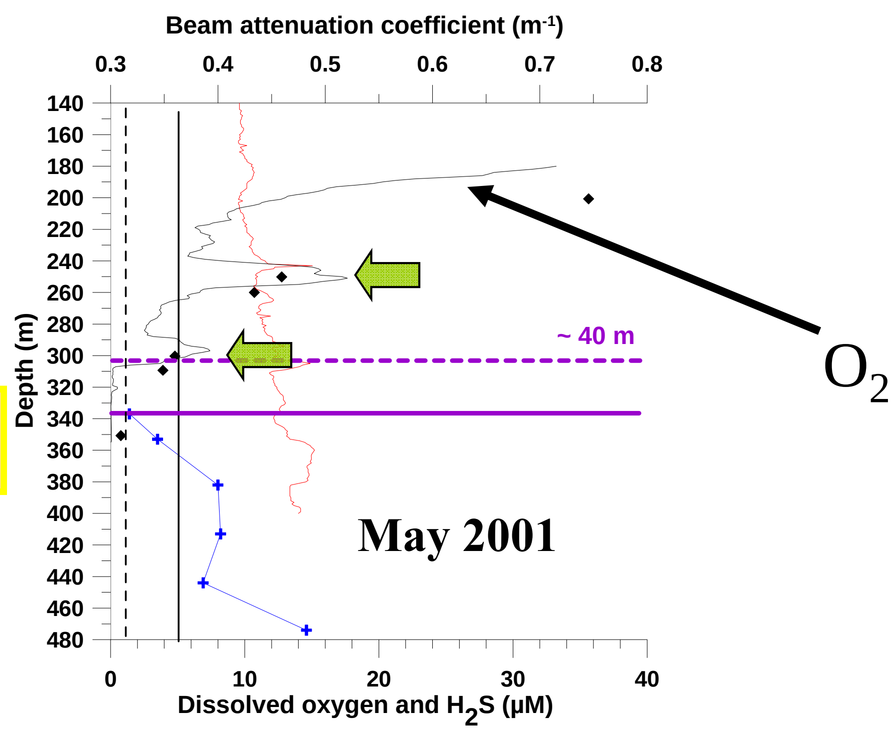
Profiles with No "Ventilation"



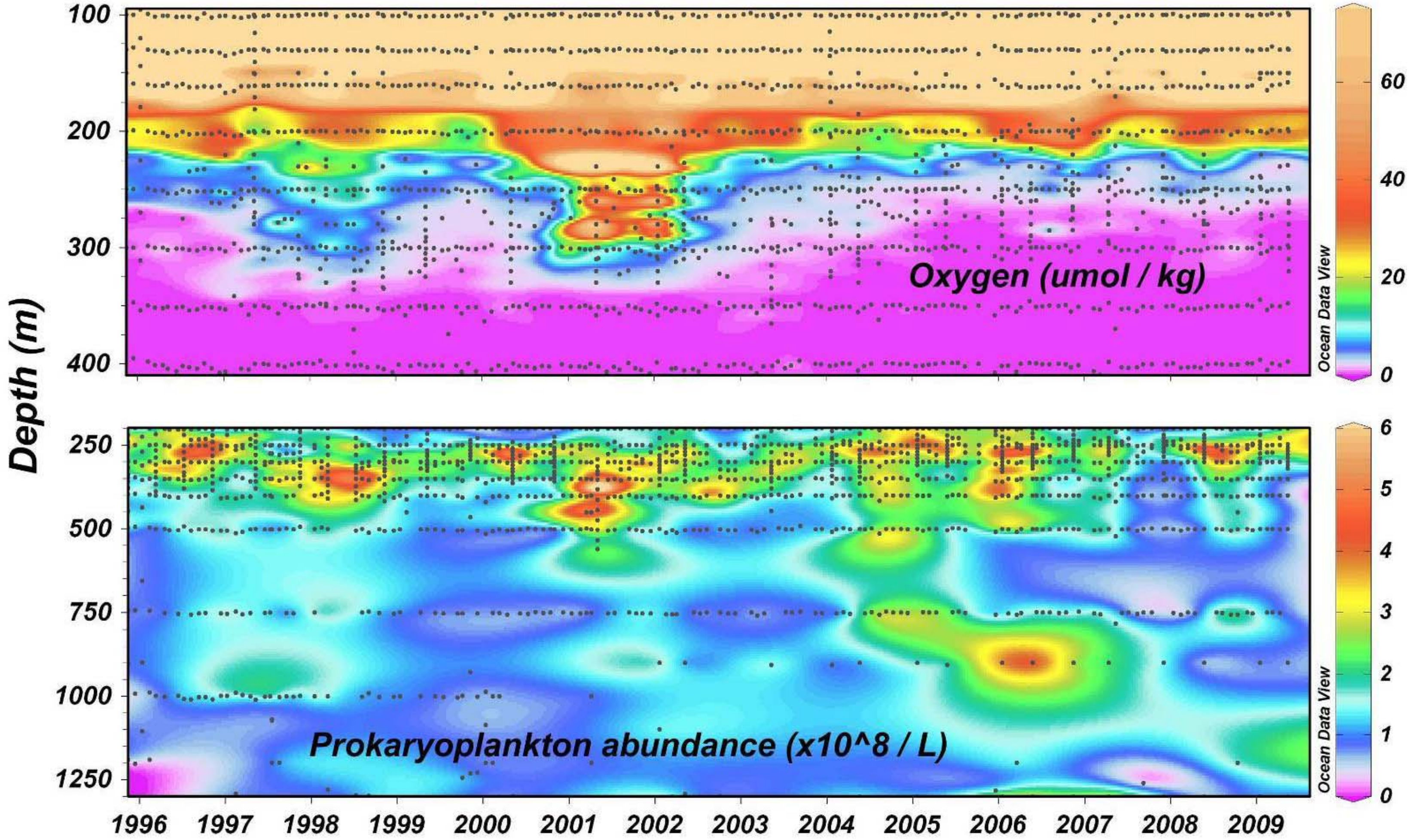
- ***Ventilation has effects on the depth and separation of the O_2 and H_2S boundaries***

Profiles showing "Ventilation"



Purple lines indicate upper and lower boundaries of suboxic zone

Oxygen and life on the edge



Prokaryoplankton abundances in redoxcline and deeper are poorly correlated with any measured variables but there is some suggestion of relation with $[O_2]$.

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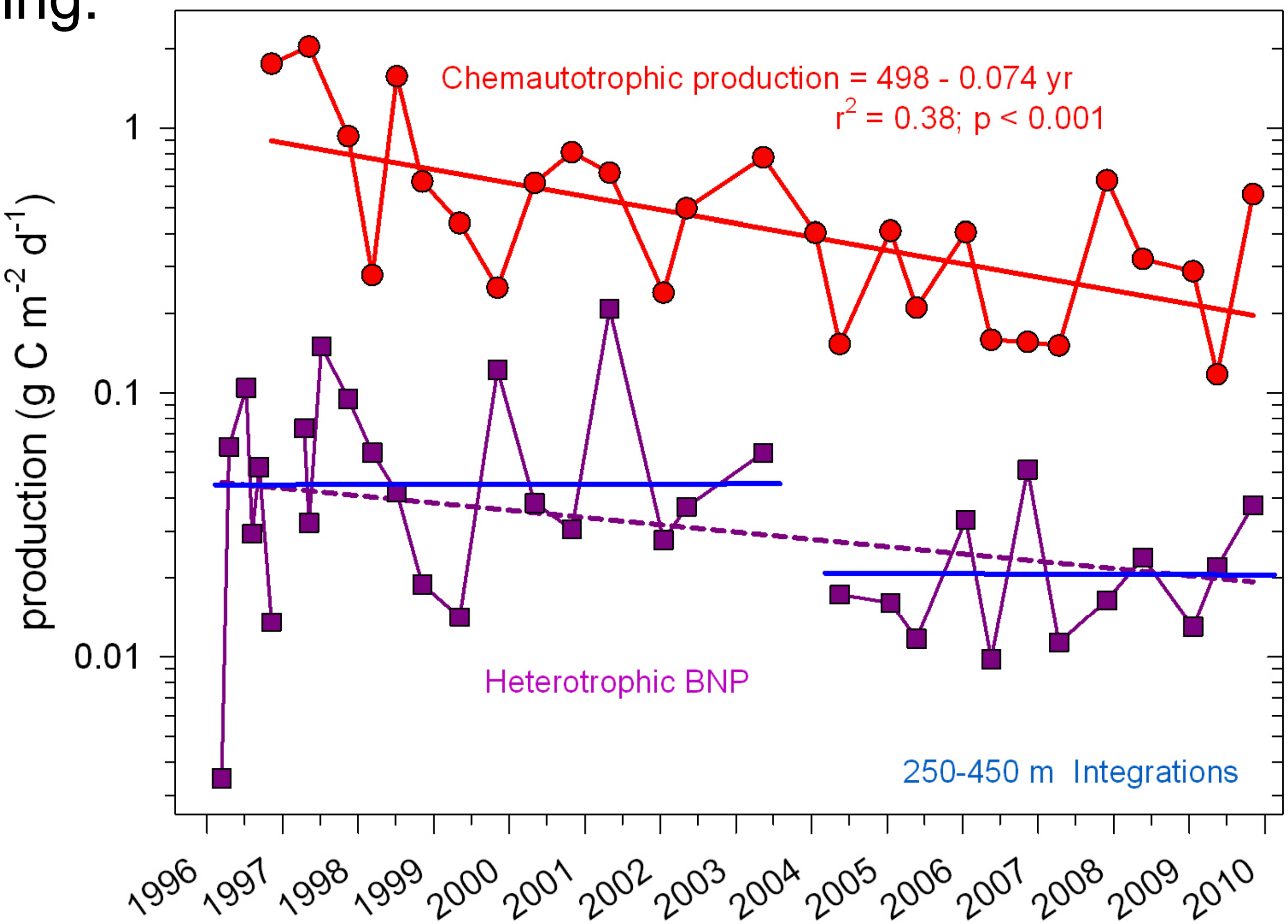
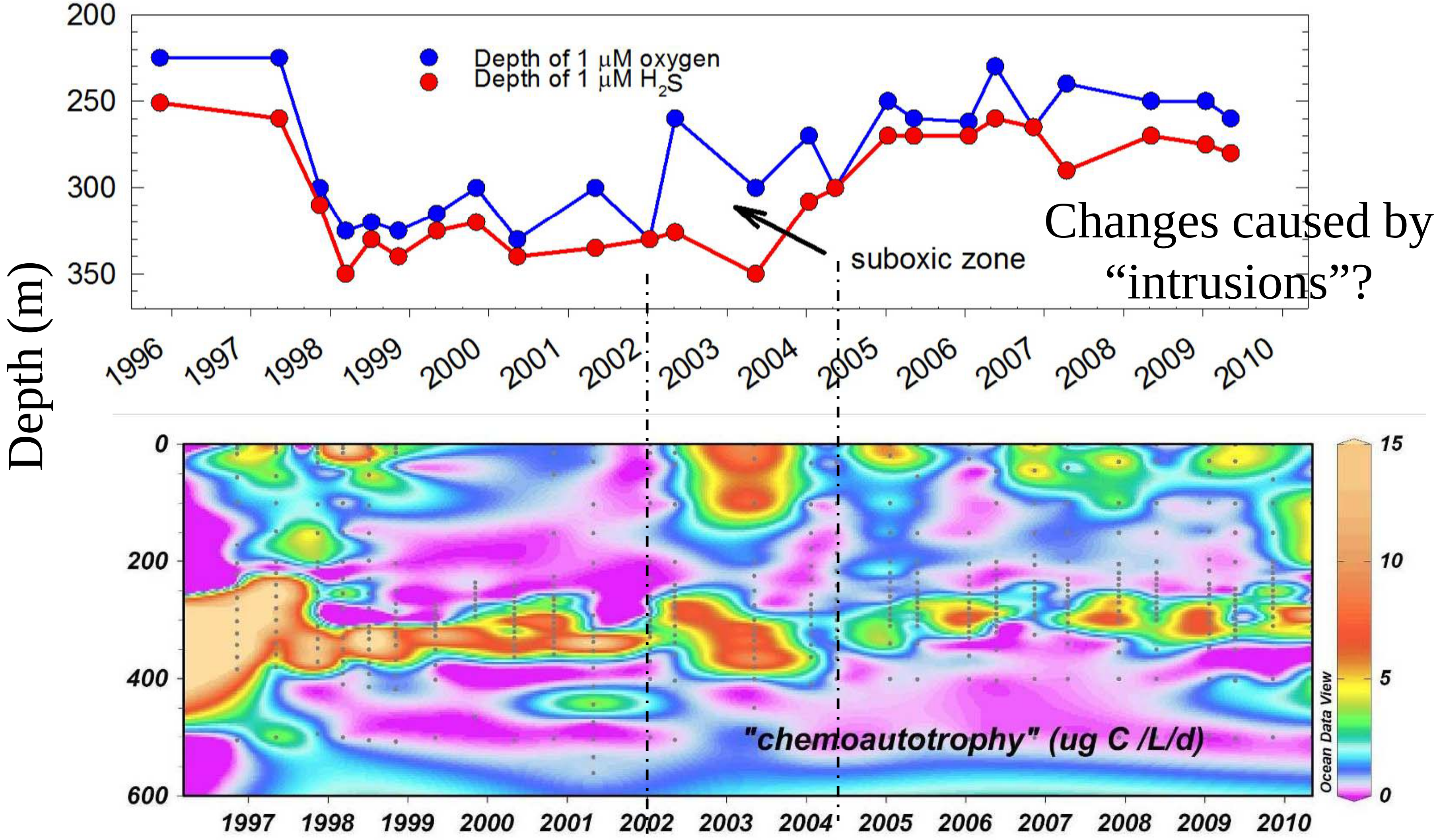
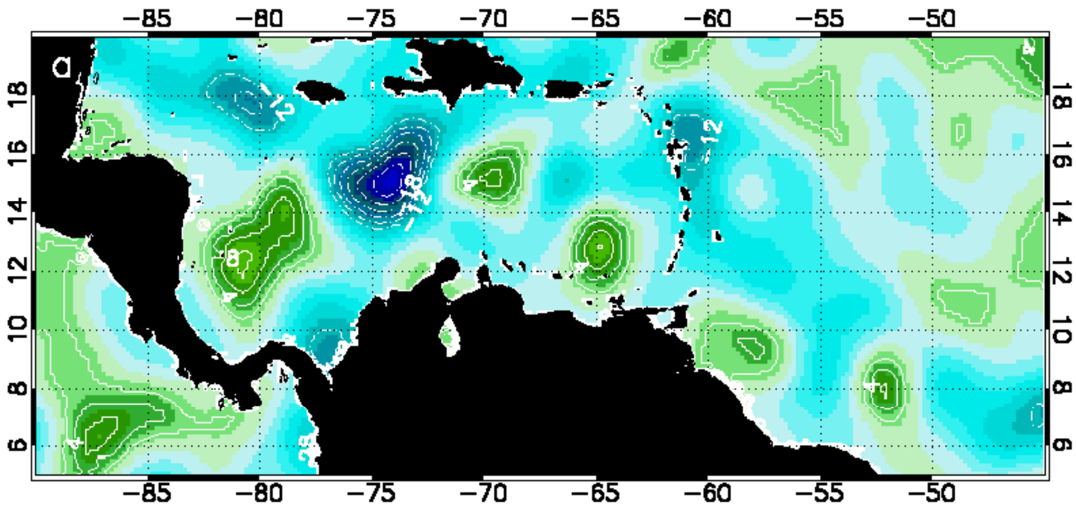
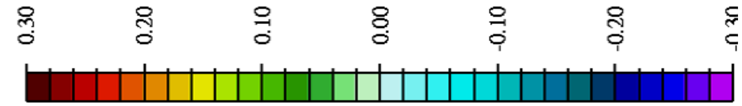
Within redoxcline, both chemoautotrophic and heterotrophic bacterial production may reflect regime shifts and appear to be declining.



Chemoautotrophic production across redoxcline appears responsive to position and thickness of suboxic zone







TOPEX-POSEIDON IMAGE: ALTIMETER OI, SEA LEVEL DESVIATION (m)

Eddies affect circulation and ventilation of Cariaco Basin

(but not yet clear why ventilation has decreased)

Satellite altimetry study by Yrene Astor

EDIMAR

Ventilation events. Total = 27
Eddies occurrence = 43

Ventilation events associated to eddies	*18*	*67 %*
Ventilation events no associated to eddies (Sep-98, Jul-99, May-01, Jul-01, Mar-02, Jan-05 and May-05)	*7*	*27 %*
Ventilation events suspected to be associated to eddies (Oct-97 and Apr-01)	*2*	*8 %*

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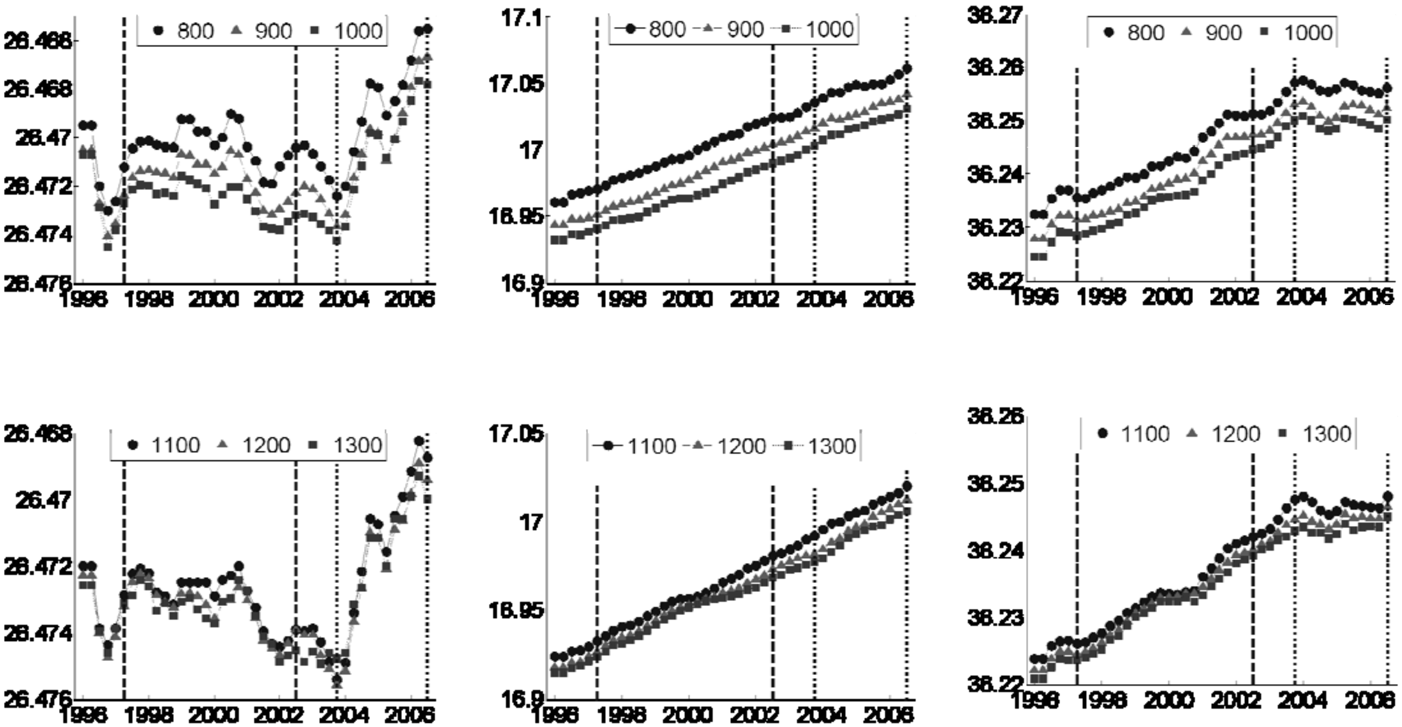
Density (σ_t) | Potential Temperature | Salinity

Lower dens.

Higher



Lower dens.

Higher

Trends at depth in the basin show a generally increasing density between 1998 and 2001, followed by decreasing density until 2004. Modeling efforts suggest regime shift due to a change in the extent of intrusions to depth in the basin (A. Samodurov and S. Konovalov at MHI, Ukraine).

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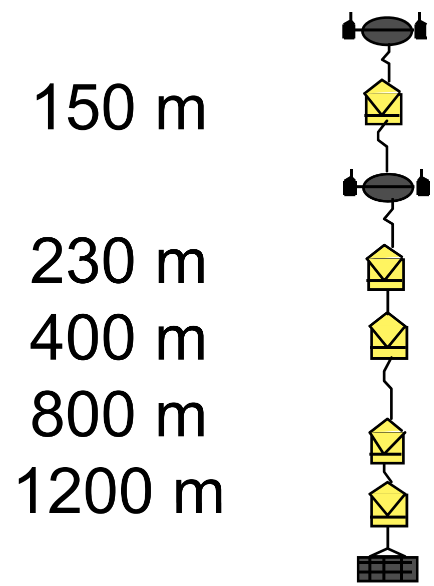
Sediment trapping:
Robert Thunell, Eric Tappa /USC



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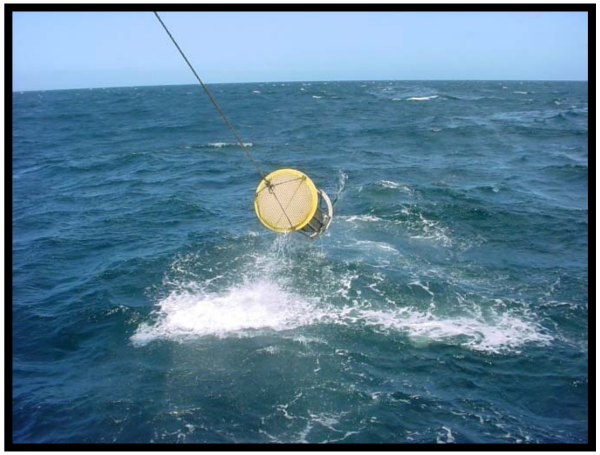
Sediment trap sample collection



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Sediment trap samples

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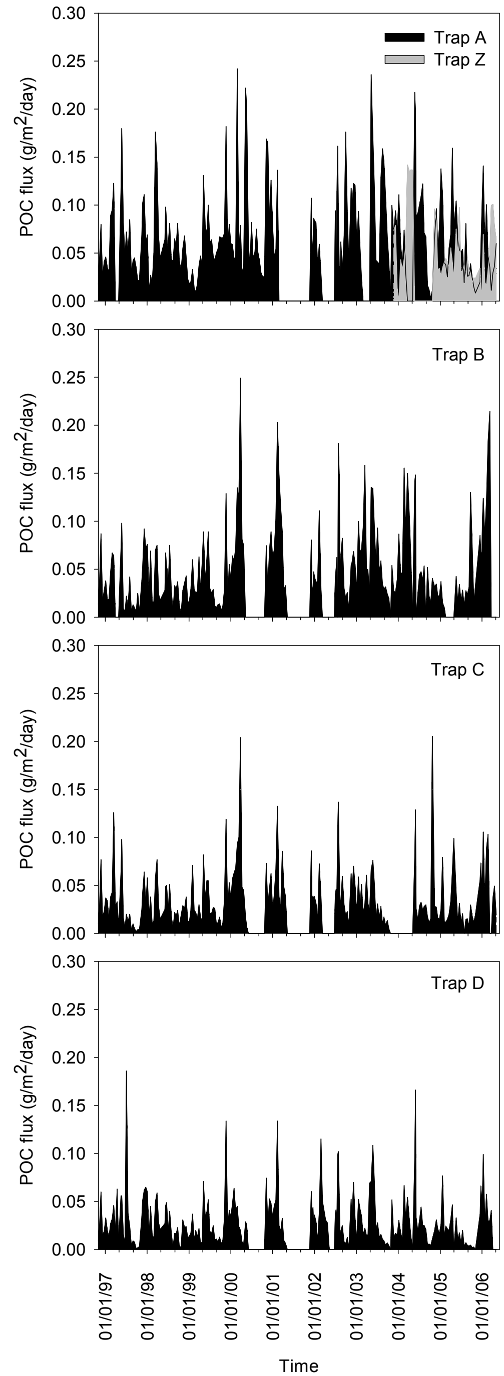
Particulate organic carbon flux

- Organic particle flux at 1300 m is
  ~0.07 gC $m^{-2}d^{-1}$
  (Thunell et al., 2007)

- ~1.3% of primary productivity reaches the bottom



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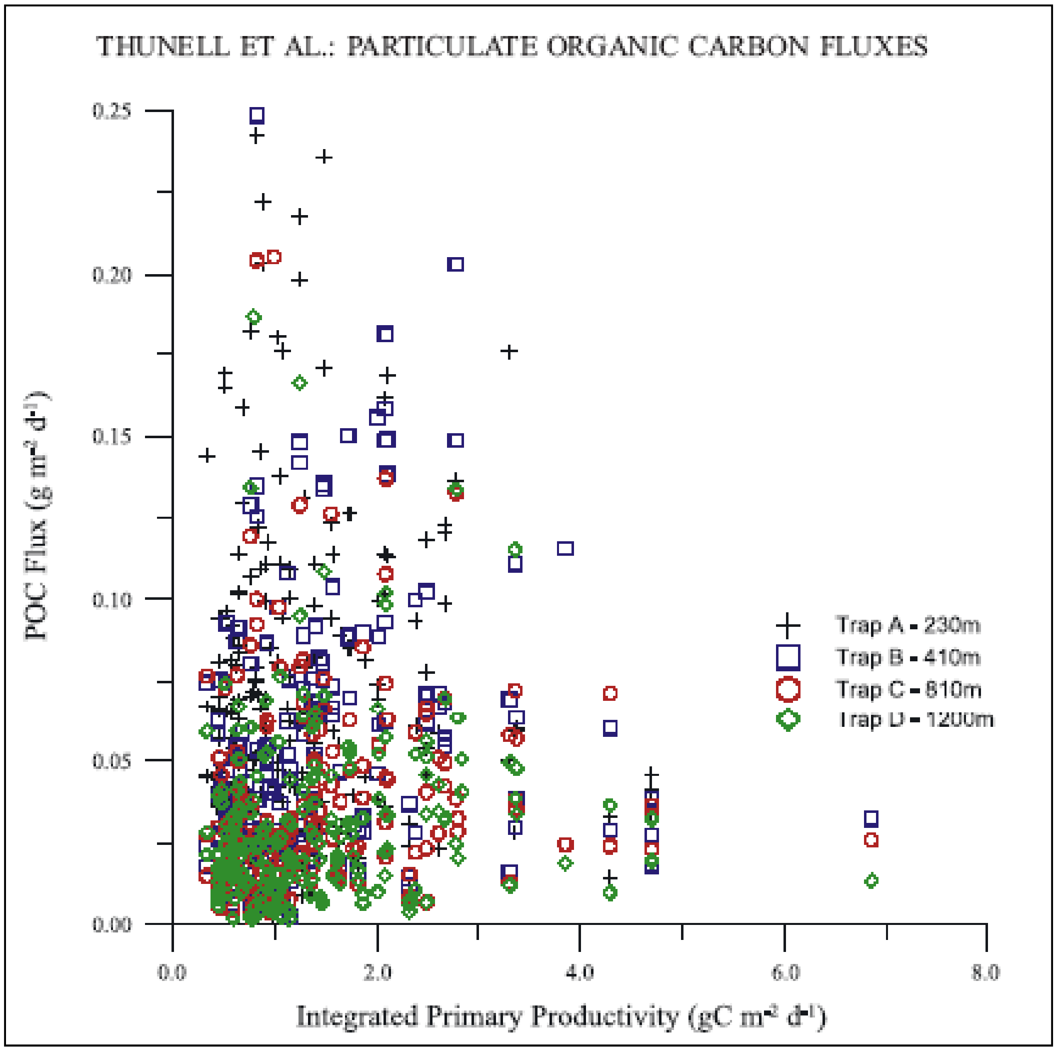
Particulate Organic Carbon Flux vs. Primary Productivity



From Thunell et al., 2007

No simple relationship!

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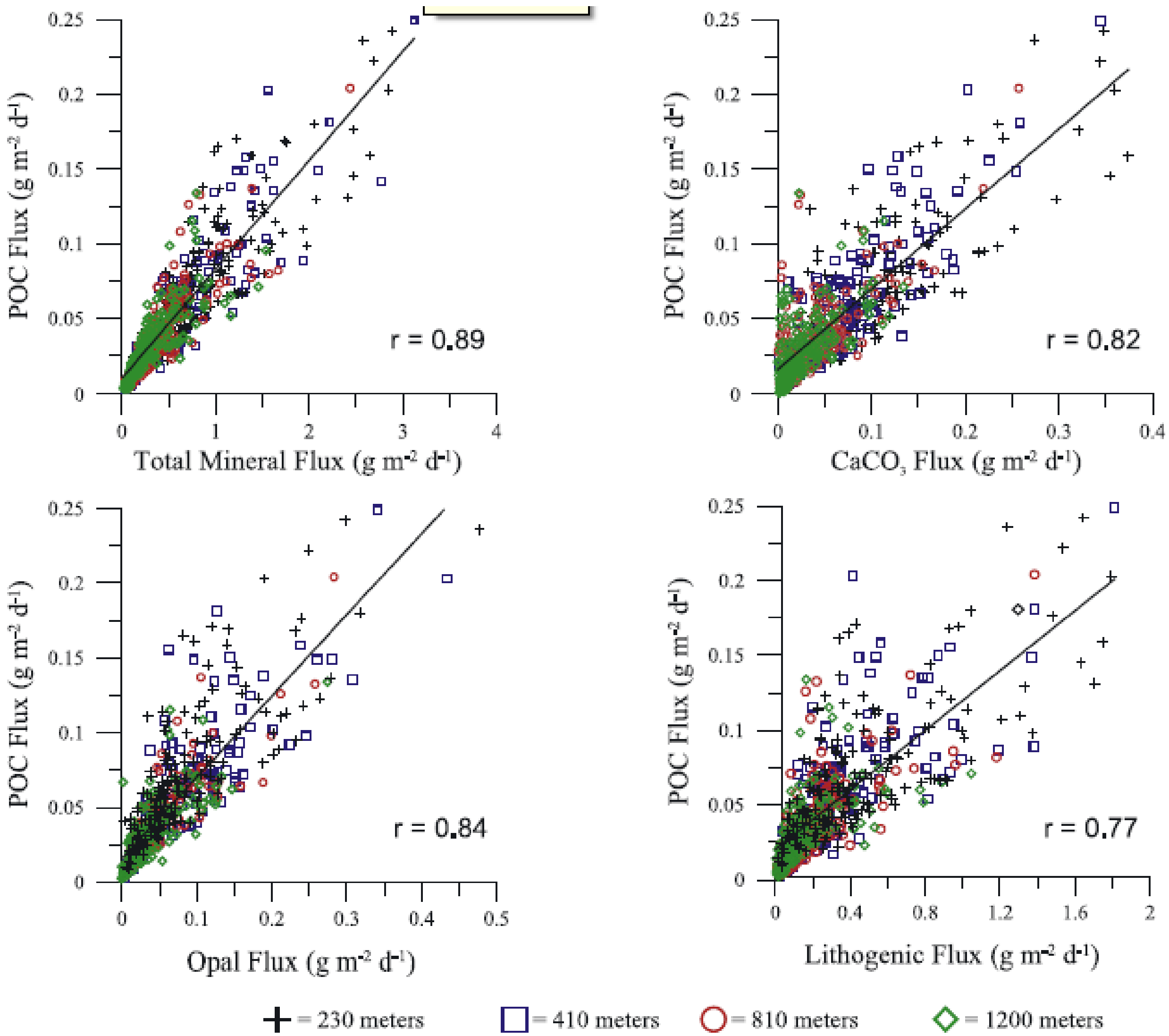


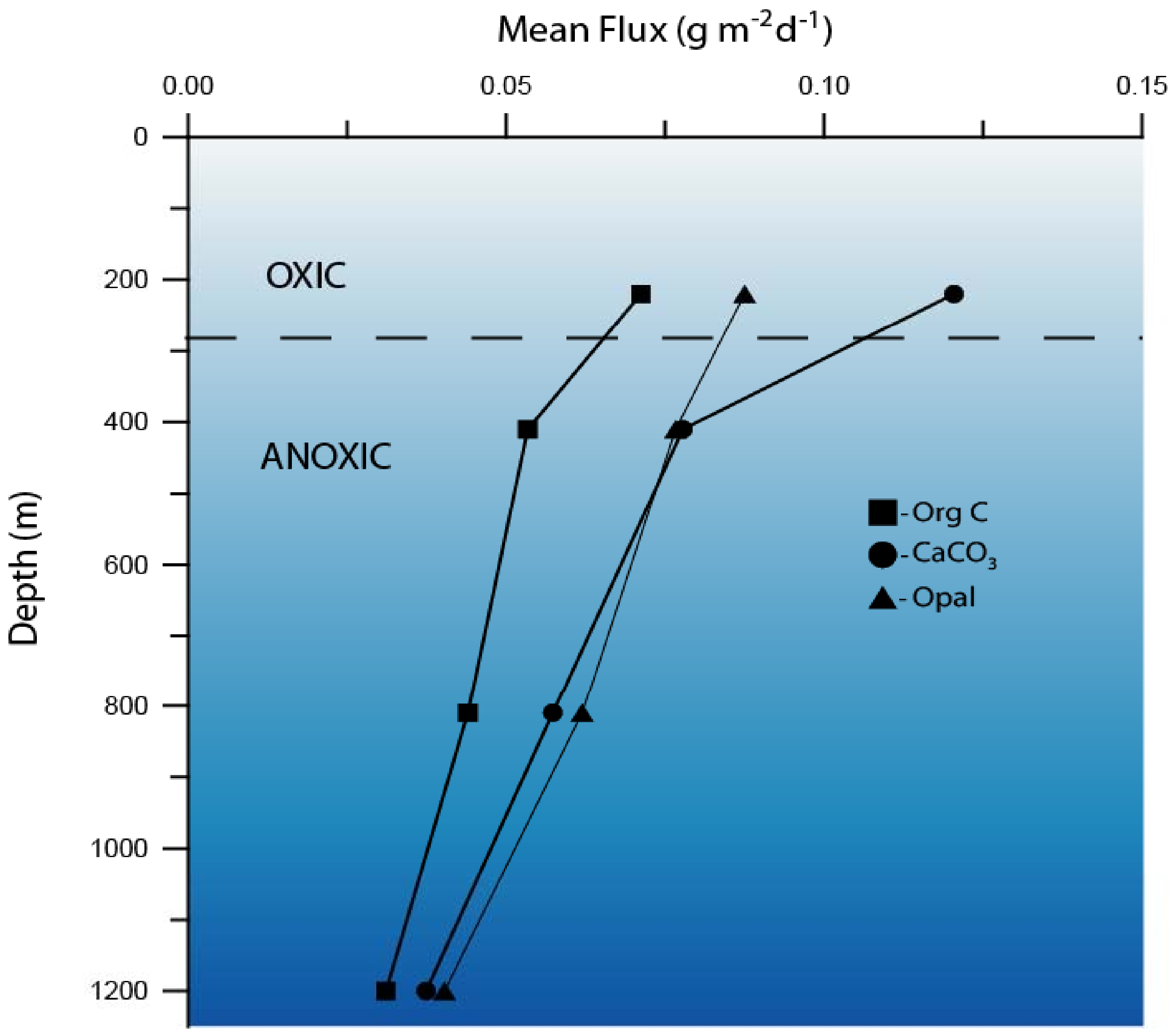
Figure 4. POC flux versus total mineral, carbonate, opal and lithogenic fluxes for Cariaco Basin. All fluxes are in g m^{-2} d^{-1}. Best fit linear regression lines and correlation coefficients (r) are shown.

POC flux is strongly related to mineral particle flux

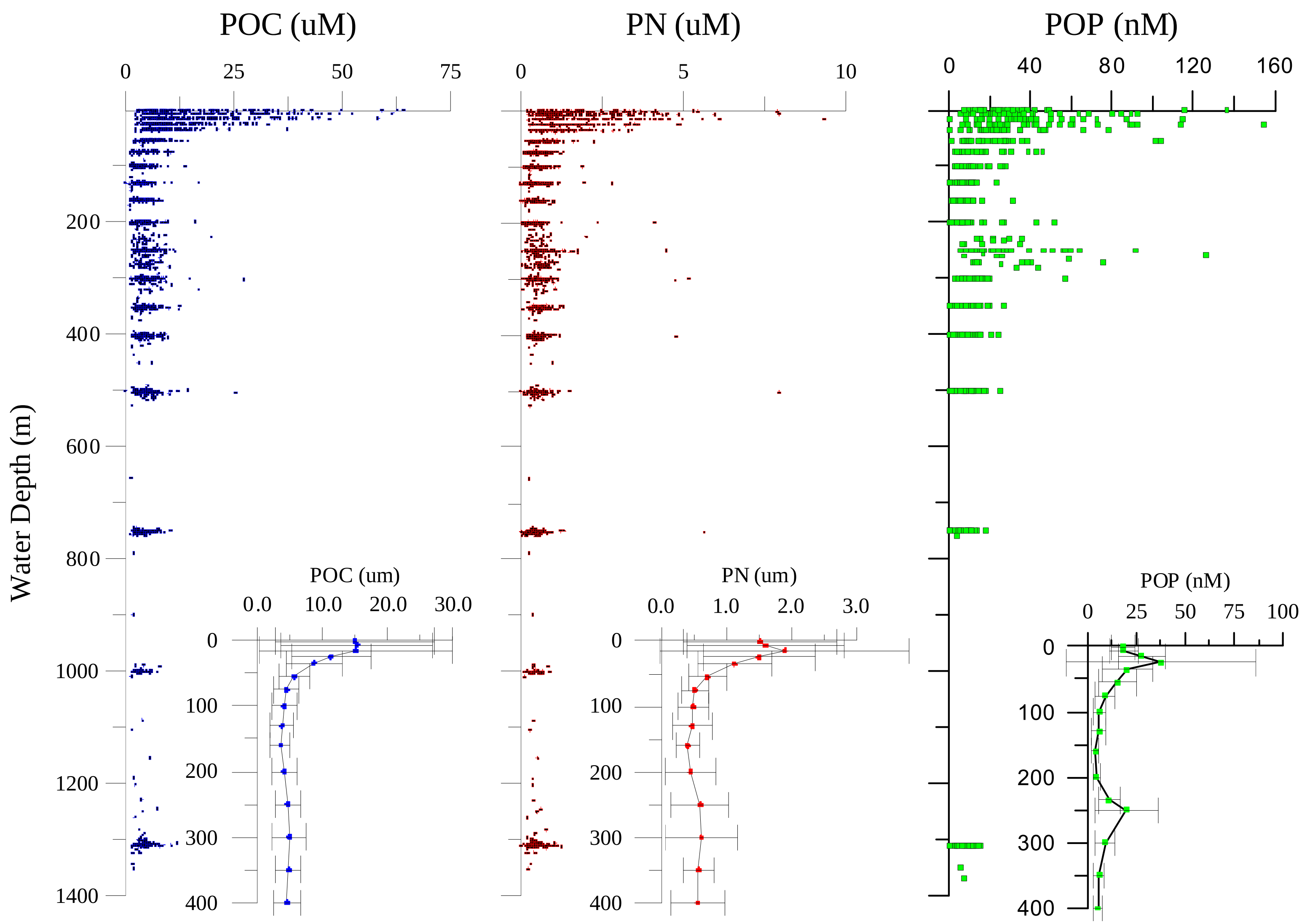
(supports “mineral ballast” hypothesis)

From Thunell et al., 2007

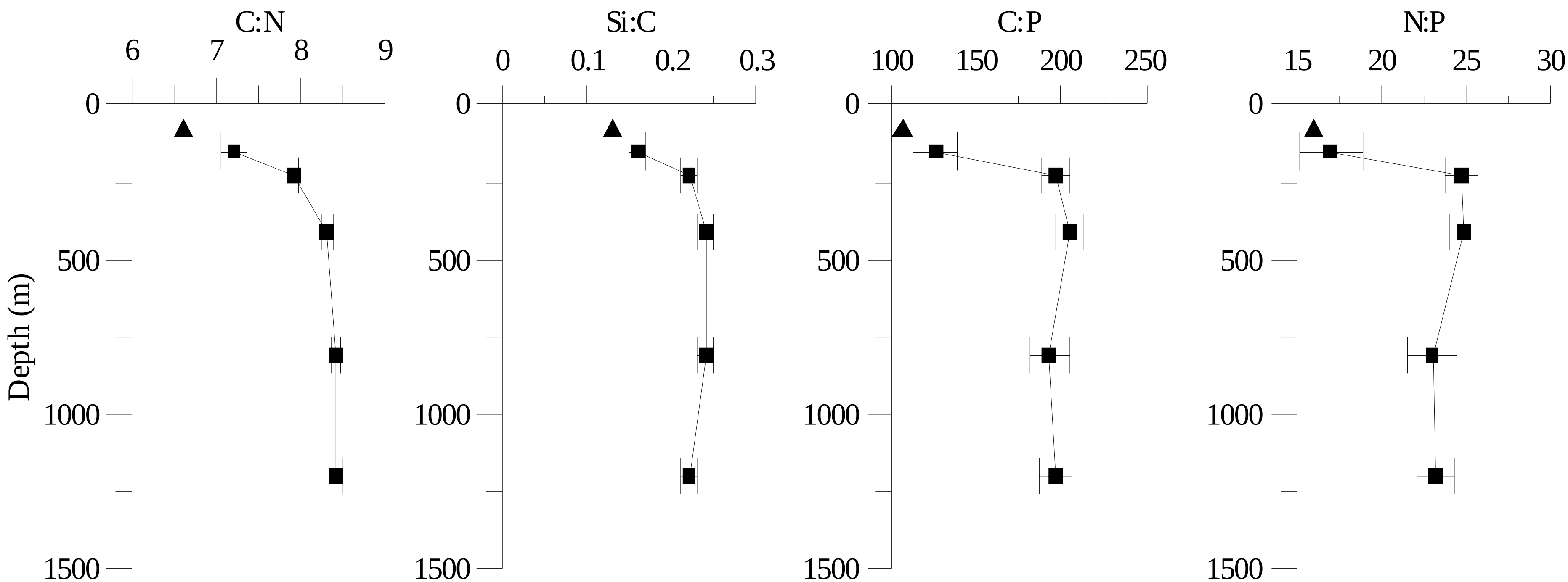
Biogenic Sediment Fluxes: Water Column Remineralization



Suspended Sediment Composition

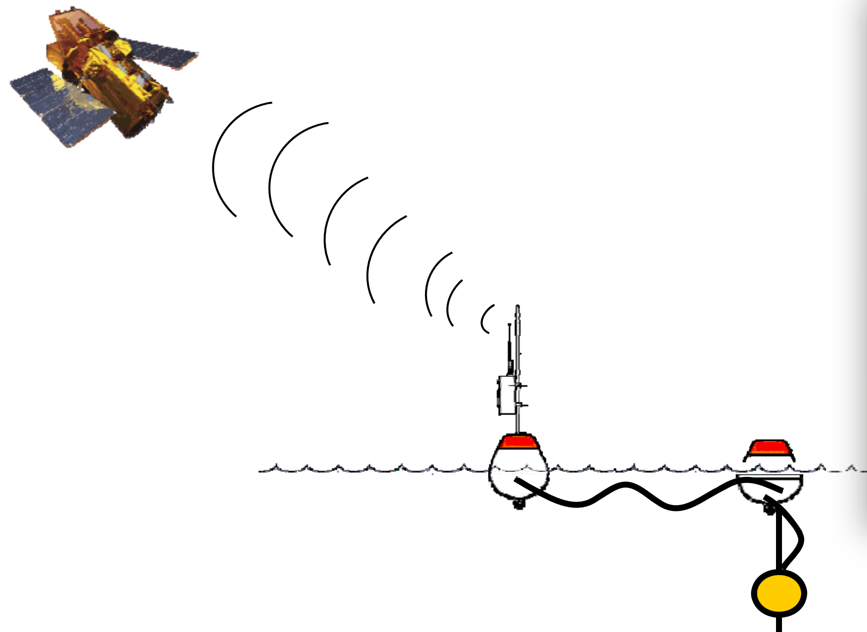
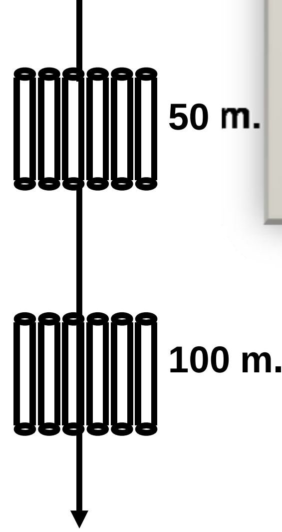


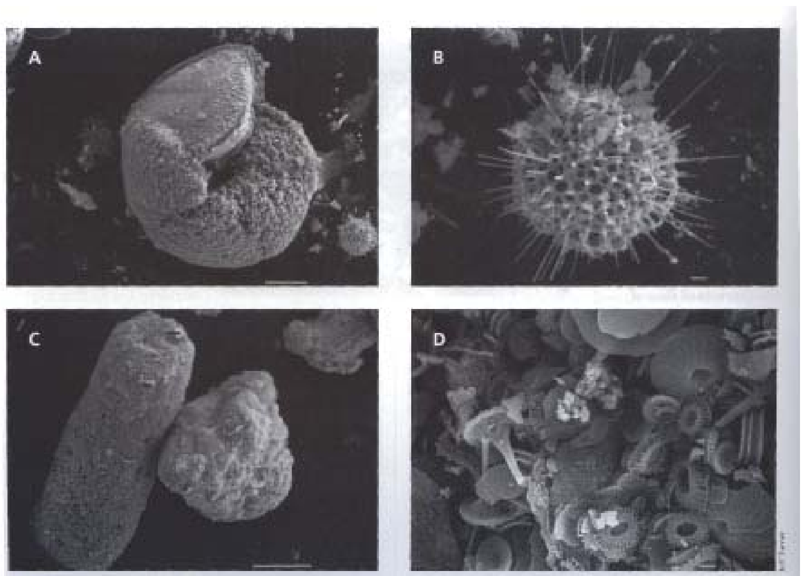
Depth-Dependent Changes in the Elemental Ratios of Sinking Particles

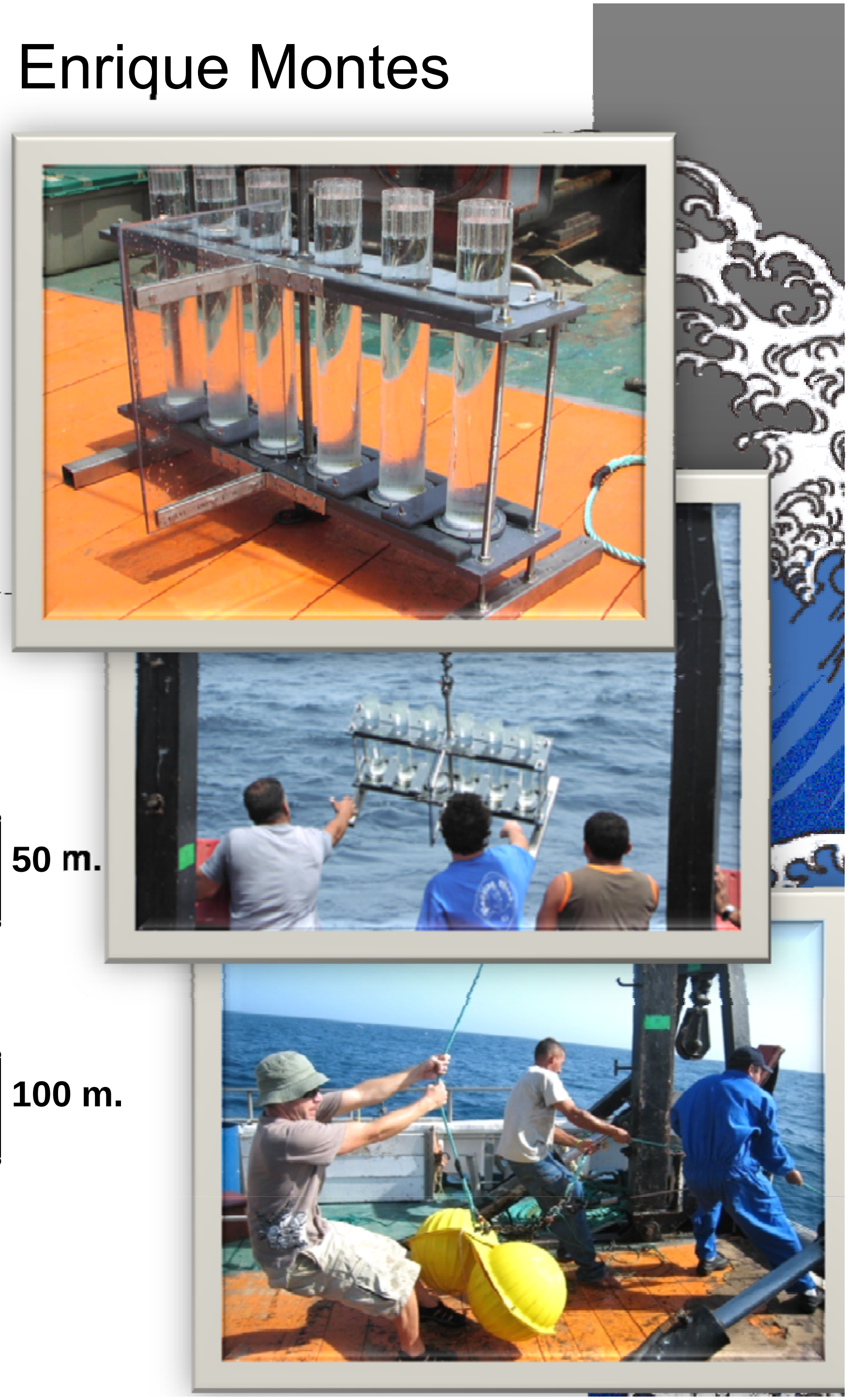


▲- Redfield ratio

Floating / drifting sediment traps: Enrique Montes





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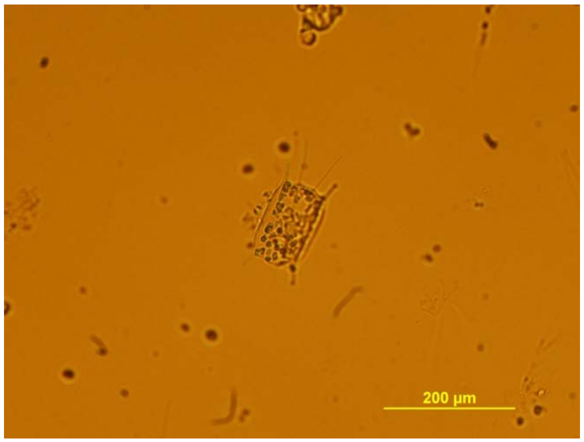
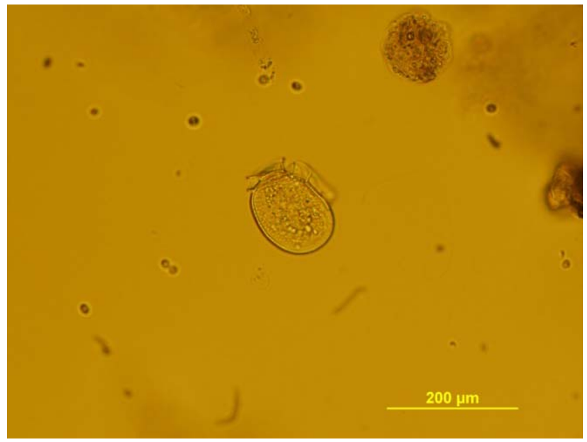
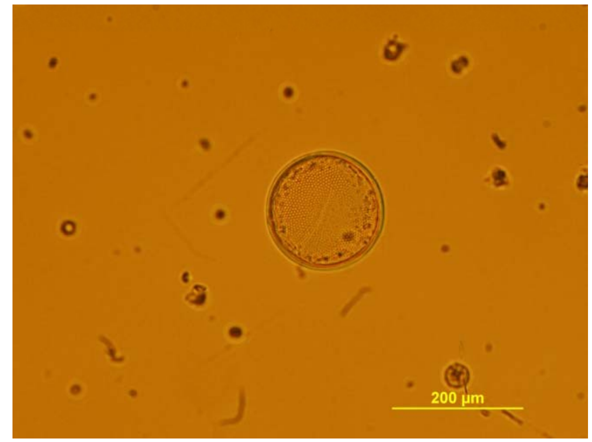
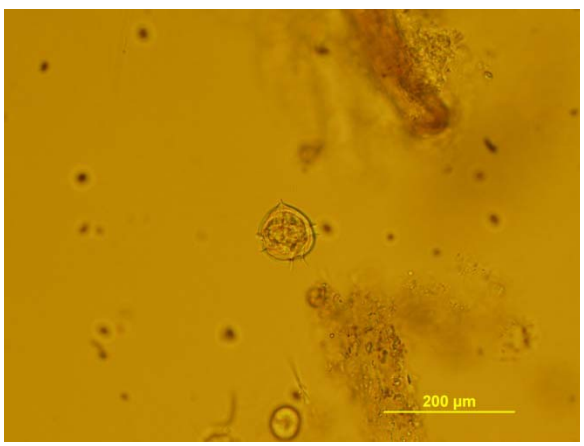
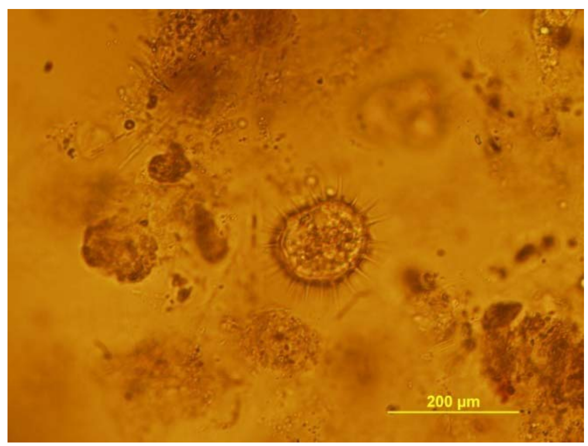
Phytoplankton captured at 50 and 100 m.











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In situ filtration pump

Gino Gonzalez/COT

Mounted on rosette

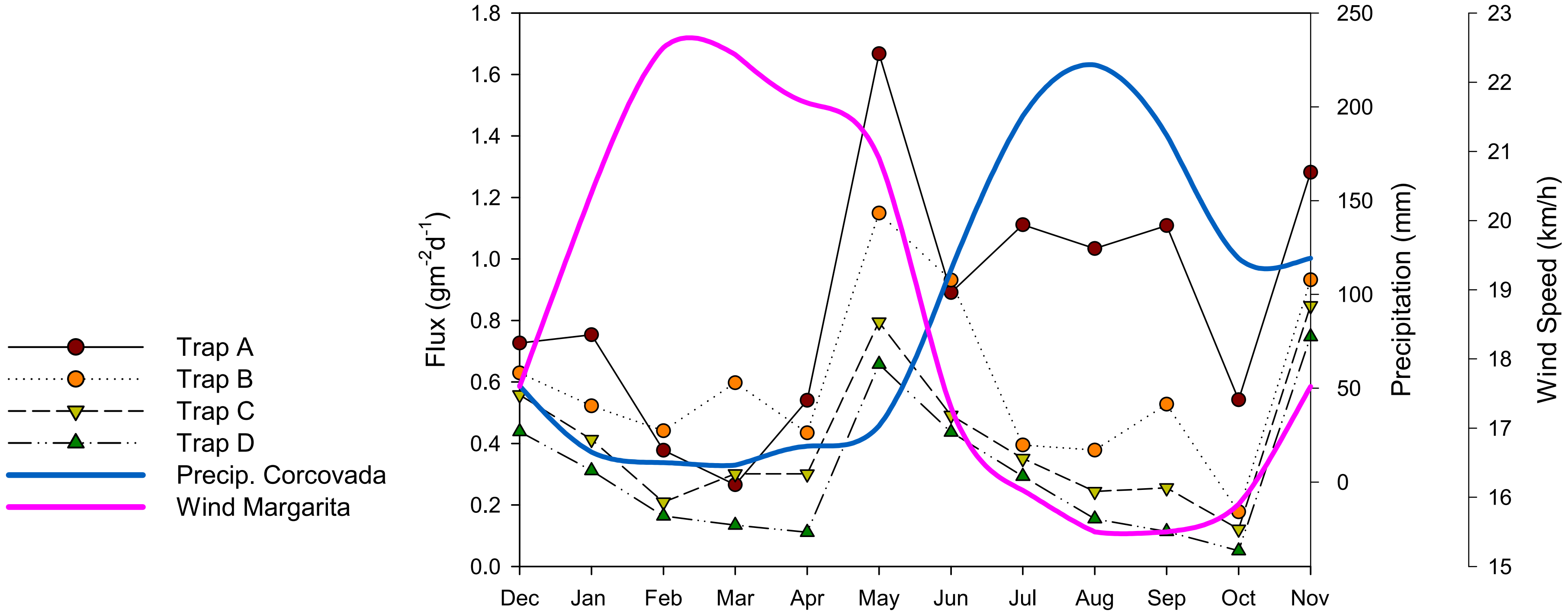
Biogenic fluxes within the Cariaco euphotic zone

- Fluxes of POM and minerals within the top 100 m follow seasonal cycle (higher during upwelling)
- Mean POC flux decreases by an order of magnitude from the base of Ez to the oxic-anoxic interface
  - from ~0.50 to ~0.09 gC m^{-2} d^{-1}
- POC in Ez is more enriched in ^{13}C during upwelling than during non-upwelling periods
  - -19.5 vs. -22.8
- Export ratios in the Cariaco Basin are 18 - 44%

Nitrogen isotope signal of sinking particles

- $\delta^{15}N$ of sinking PN tends to be below the annual average (4.4‰) during both Jan-Apr and Sep-Nov, and higher during transition months (May-Aug)
- $\delta^{15}N$-PN from spring bloom appears to be influenced by nitrate from upwelling and intensity of Trade winds. Years that have strong upwelling show particles during the spring bloom with low $\delta^{15}N$ (< 4.4 ‰), and vice versa (> 4.4 ‰)
- $\delta^{15}N$-PN in fall seems to be affected by local nitrogen fixation, when DIN:PO_4^+ ratios drop and *Trichodesmium thiebautii is* present

Terrestrial sediment input appears to be in pulses, at the end of the upwelling season and during the rainy season



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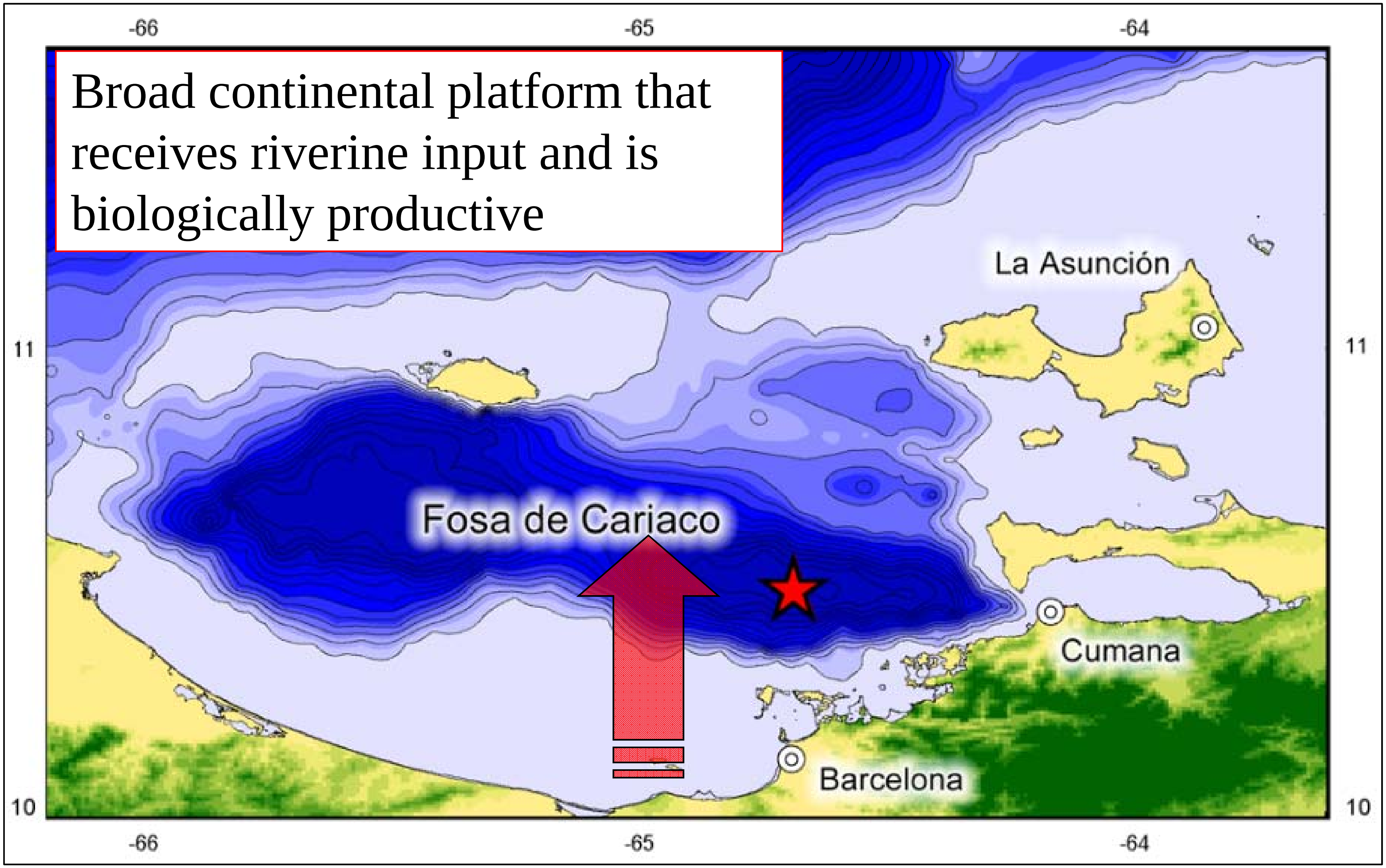
Sediment transport hypothesis



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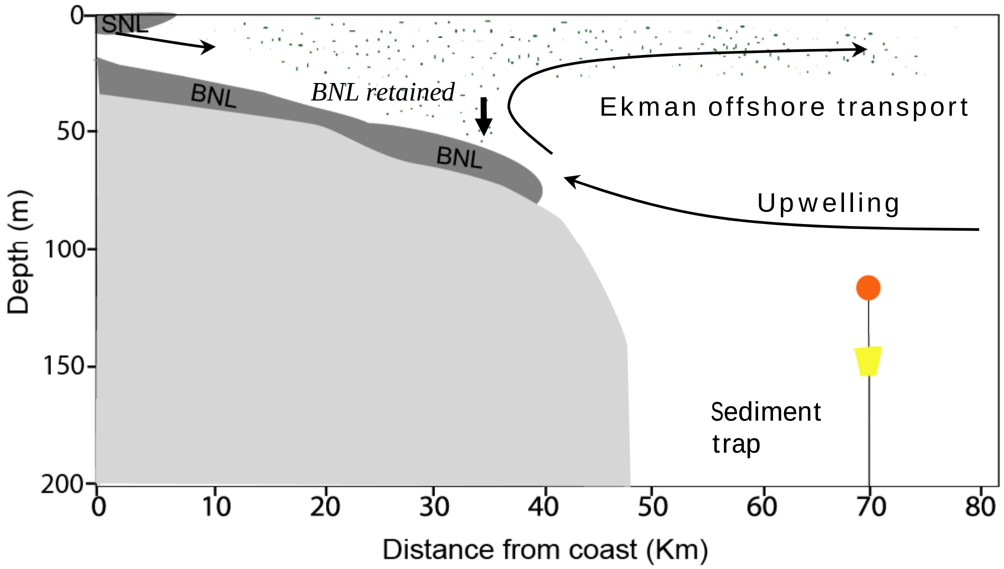

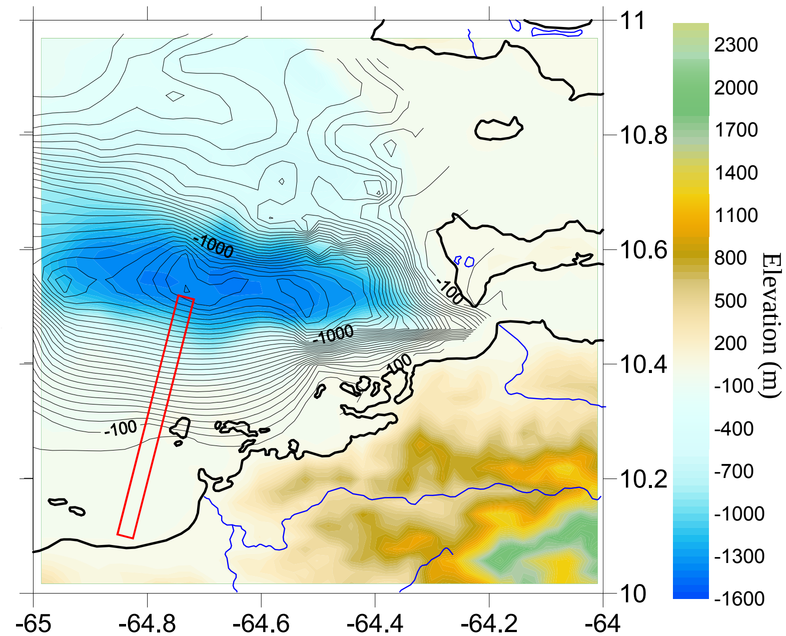

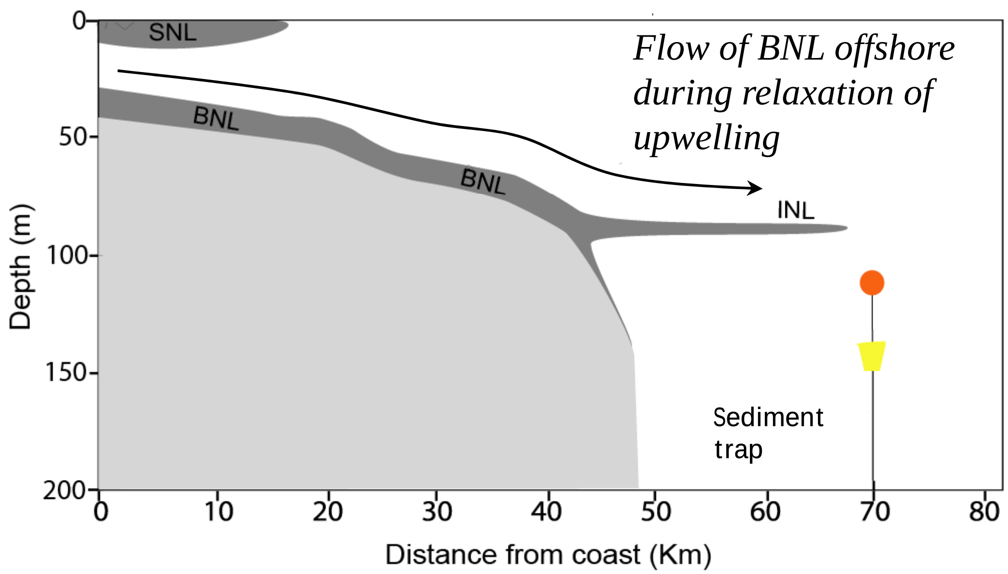

Conceptual model of terrigenous sediment delivery (Laura Lorenzoni)

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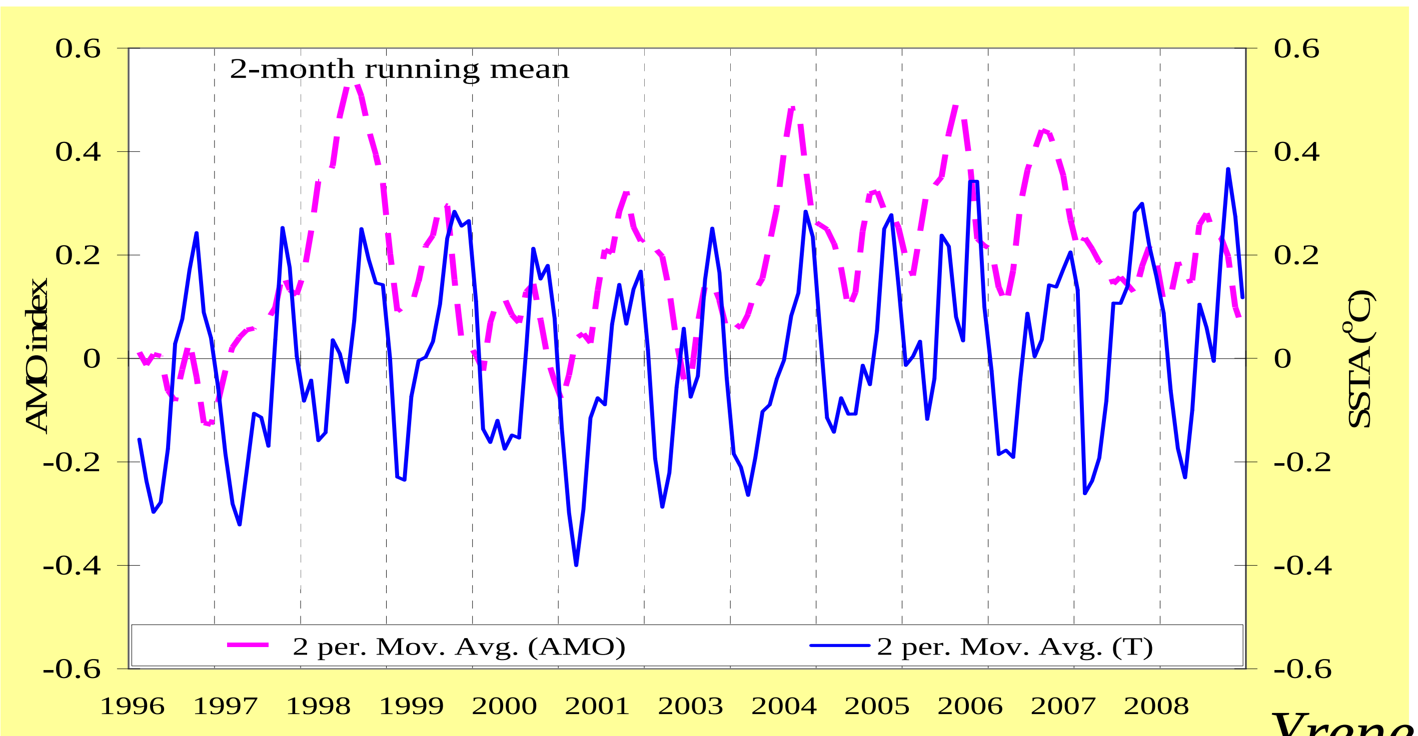
Is any of this variability related to climate indices?

(Possibly, but statistically weak)

SST and
Atlantic Multidecadal Oscillation:
Weak / $r = 0.48$, $p < 0.01$ at lag 2



Yrene Astor / EDIMAR

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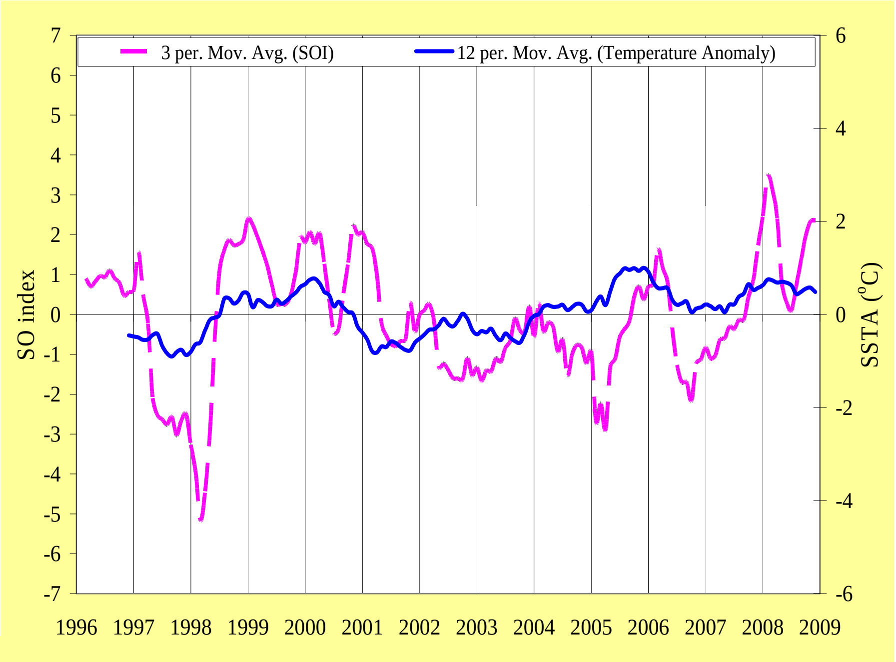
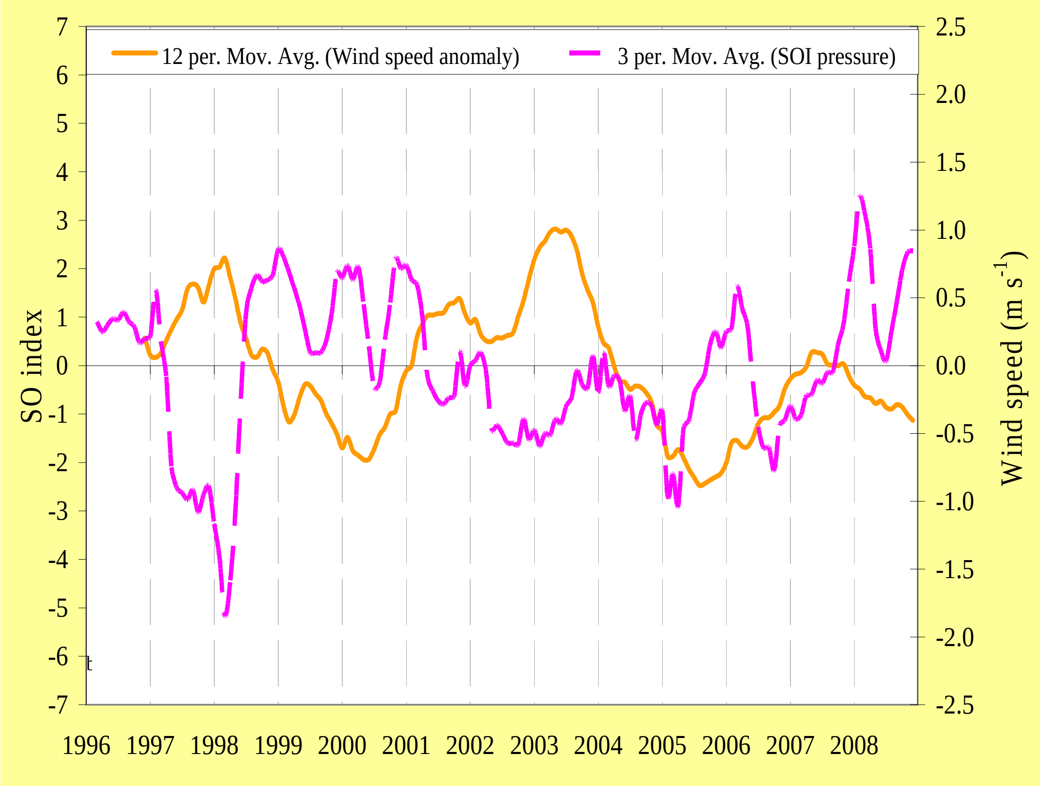
SST and ENSO / SO index:
Weak / $r = -0.25$, $p < 0.05$
(3 month lag)



Weakening of the winds and warm periods lagging negative SO index



Crosscorrelation analysis: WSA lagging SO index by 1-2 months

$r = -0.35$, $p < 0.01$

Methods manual (Eng./Spanish)

MANUAL DE MÉTODOS PARA EL ANÁLISIS DE PARAMETROS OCEANOGRÁFICOS EN LA ESTACIÓN SERIE DE TIEMPO CARIACO

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EUCLIDES RADA

TABLA DE CONTENIDO

Some Key Findings

Trade Winds decreased after 2001 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.

Secondary upwelling event and production peak (Jun-Jul every year).

Cariaco Basin is CO_2 source: Upwelling delivers high DIC to the euphotic zone, raising CO_2 fugacity.

*CO_2 fugacity has increased slightly in 15 years [1996 - 2010], even with weaker upwelling

Biogeochemistry Highlights (Stony Brook)

- Episodic intrusions of relatively dense water from the Caribbean causes injection of oxidants into middle and deep waters. This results in changes in depth of the oxygen-sulfide transition and in the thickness of the suboxic zone. Intrusions do not occur “evenly” over time but show decadal scale variability.

- Declining bacterial productivity trends could be driven by: fewer lateral intrusions, lower O_2 fluxes to interface or slower bottom circulation. (Lower export production is not evident.)

- Remobilization of oxidized (terrestrial) minerals by earthquakes or by intense coastal rains result in large changes in concentrations of iron and sulfide in the basin. Iron sulfide precipitation in the water column after such events returns the system to “normal”.

- Bacterial inventories in redoxcline and anoxic zone share a periodicity (~100 d) with variances in water density, PO_4^{3-}, and $[O_2]$ within redoxcline. No strong periodicity for prokaryoplankton in photic zone.

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Sediment flux in Cariaco Basin

- *Rate at which POC flux decreases with depth owing to remineralization is similar to that previously reported for the open ocean (in spite of anoxia below 250 m)*
- *Relationship between POC flux and mineral flux is not significantly altered by water column remineralization*
- *No significant relationship exists between POC flux and primary production*
- *Mineral ballast appears to be an important factor controlling flux of POC from surface waters*

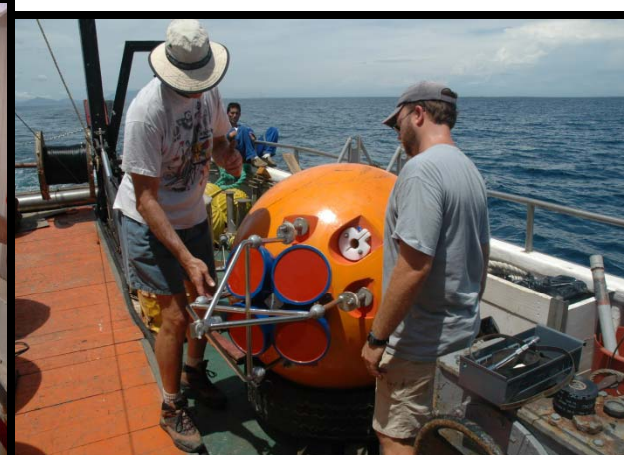
CARIACO and its people

FLASA/EDIMAR

FONACIT

NSF

Many others



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)*

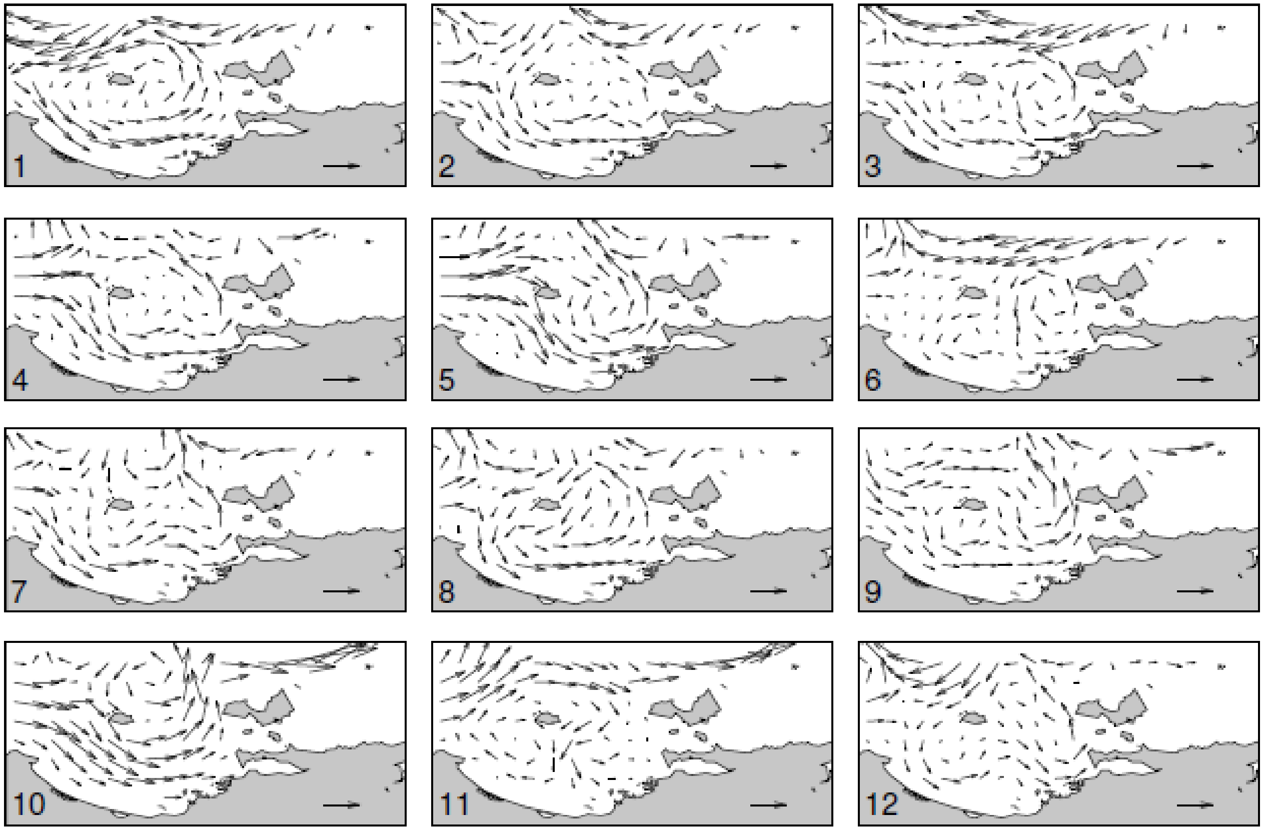
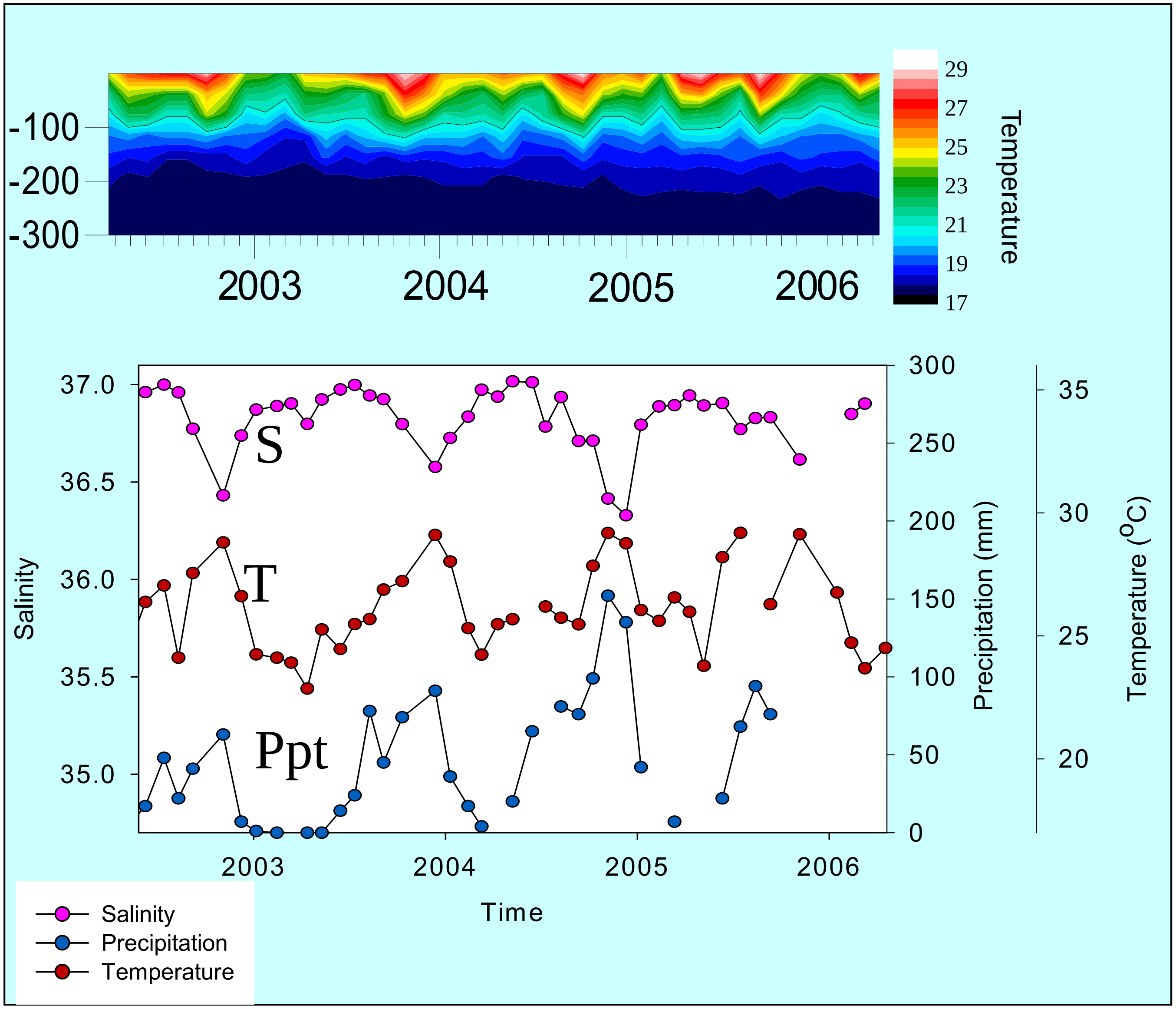


Figure 16: Currents at 50 m depth. The numbers at the lower left corner of each panel indicate the month, and a 0.2 m s^{-1} arrow is shown at the lower right corner of each panel for reference.

Circulation Model Results

(From: Aida Alvera-Azcarate, Alexander Barth, Robert H. Weisberg, 2008)

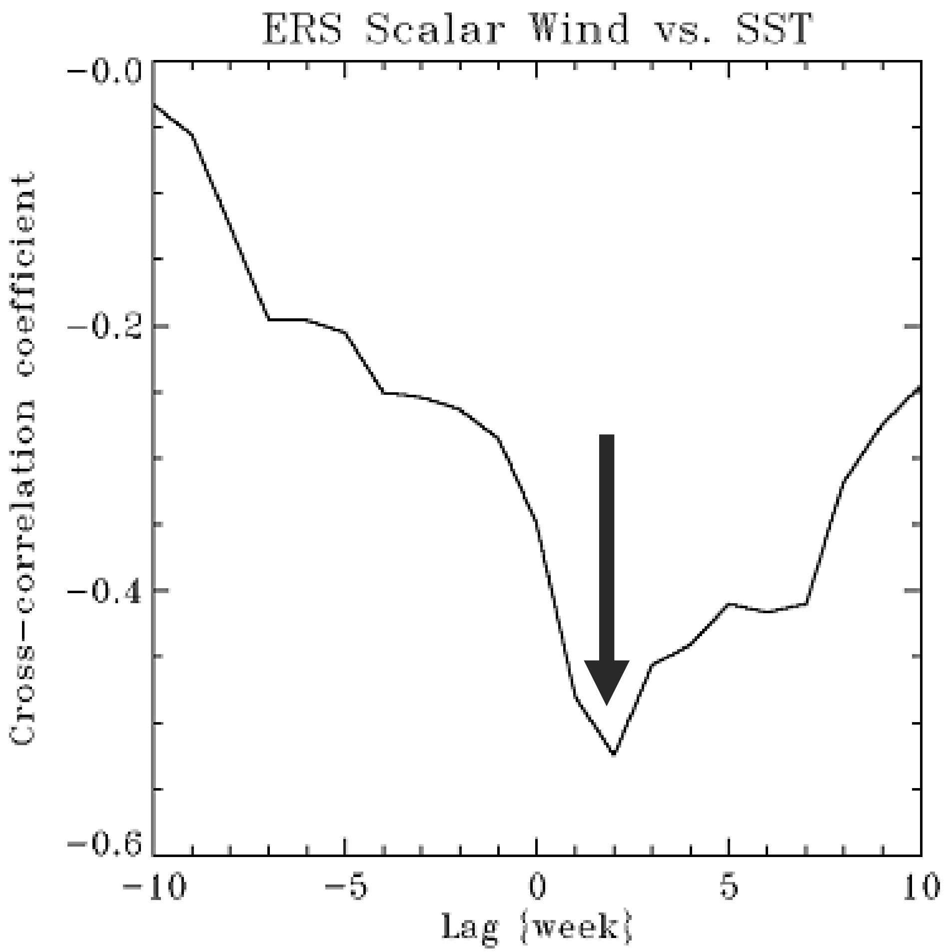
Surface conditions



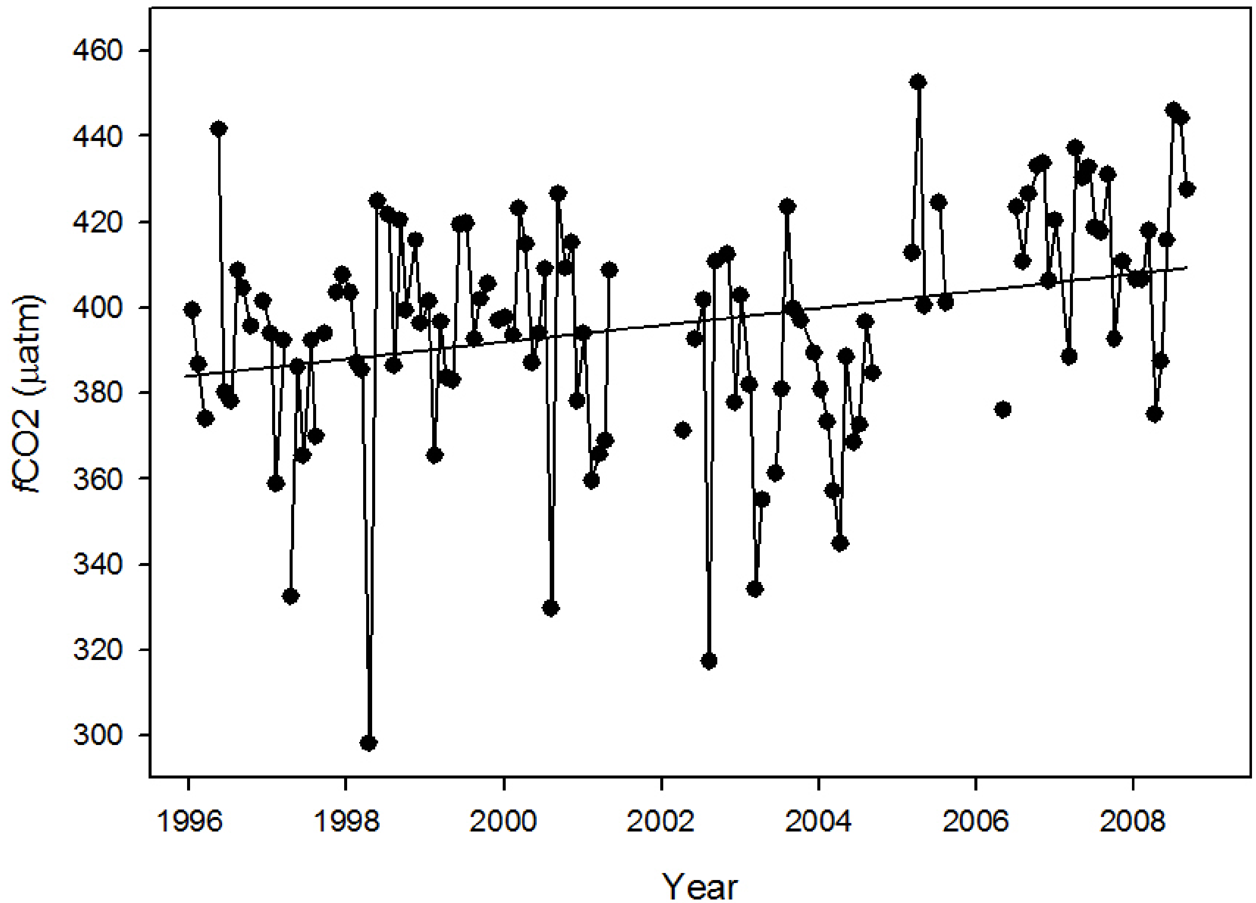
- *Upwelling evidenced as cooler temperatures during first half of year*
- *Rain/discharge influences basin during second half of year*

Wind and SST

SST lags WIND by about two weeks



CO_2 fugacity



	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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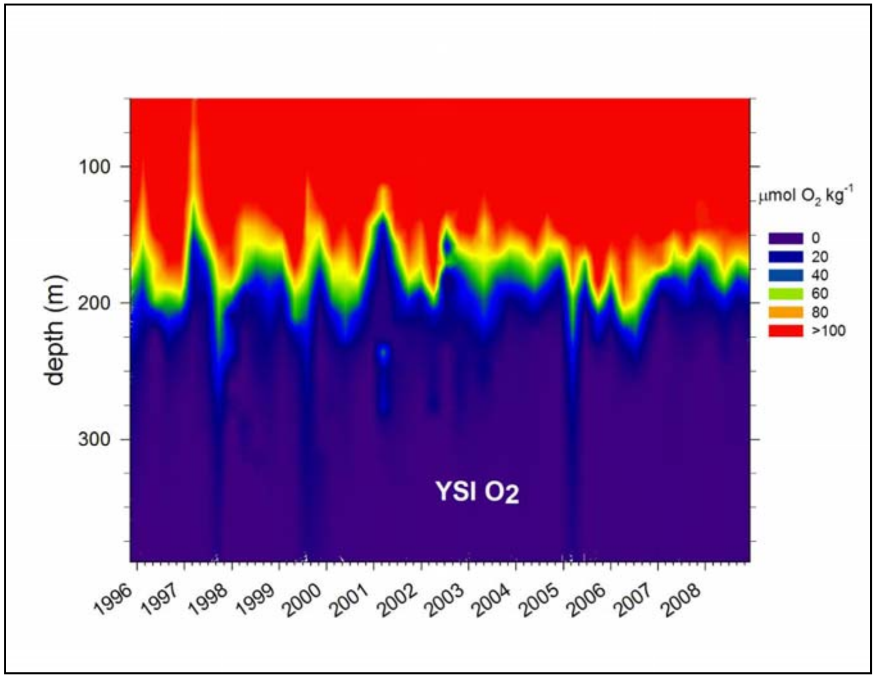
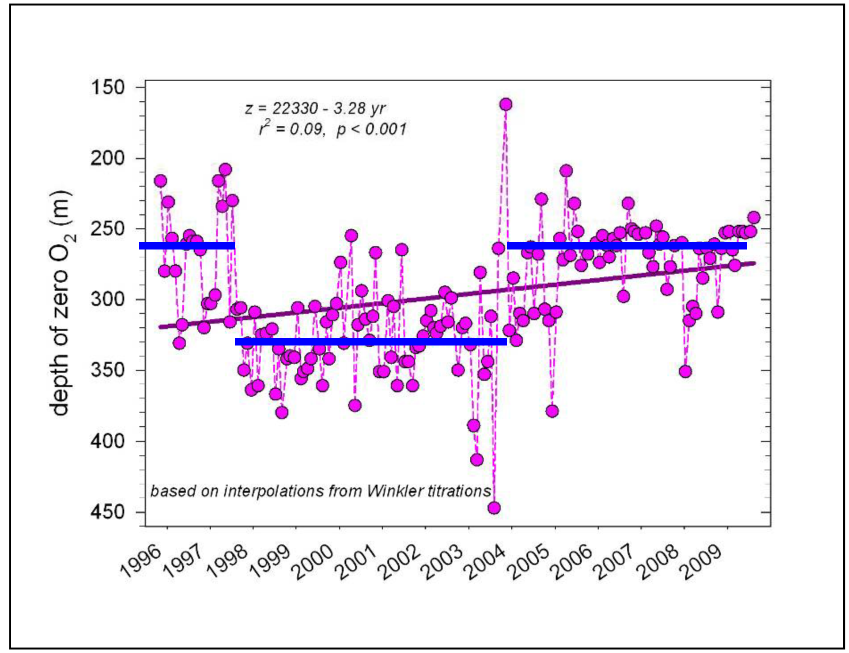
EDIMAR
ESTACION DE INVESTIGACIONES MARINAS DE MARGARITA





O_2 concentrations and depth of penetration vary considerably.

Between late 1997 and 2003, intrusions were relatively frequent but we have seen only one strong event since 2003

Depth of the oxic-anoxic boundary varies from month to month.

*Trend to a shallower interface?

*Abrupt shift in 1997 from 250->320 and then return to shallower depths in about 2005?

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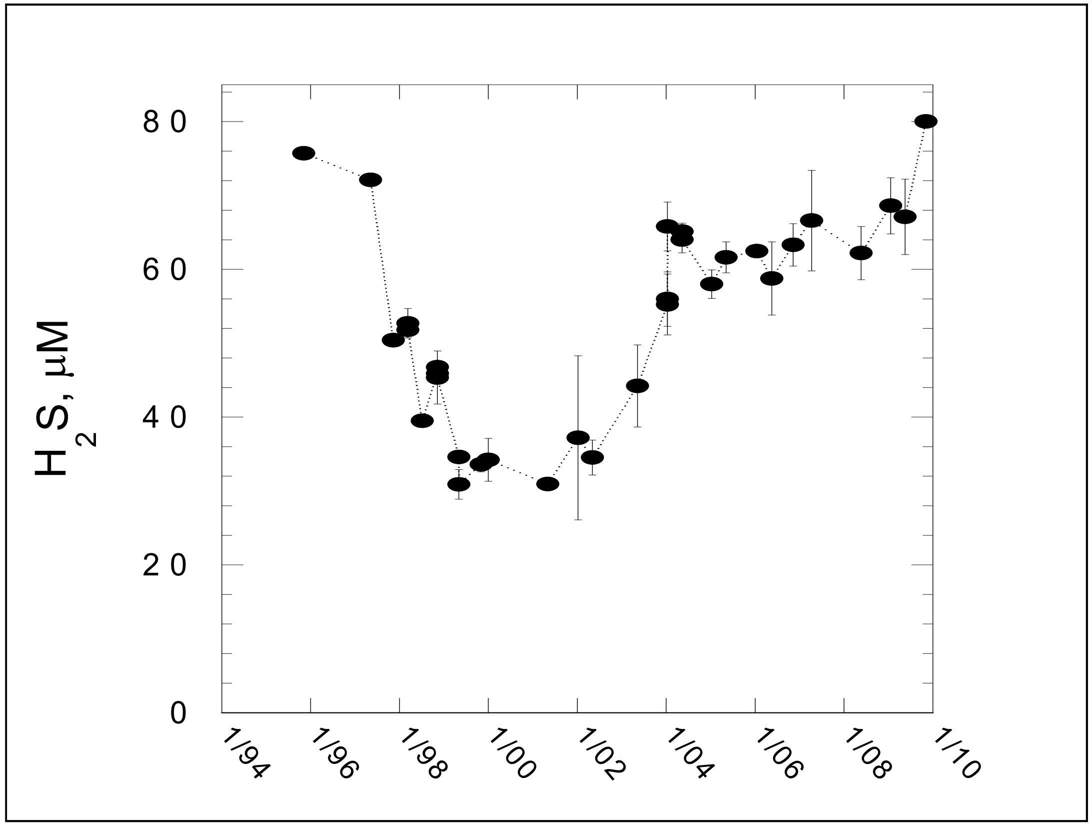
Bottom water sulfide appears to be “buffered” by intrusions of oxygenated water from outside the basin and terrestrial input of metals.

Terrigenous input also seems to cause sharp changes in iron concentration, with a recovery following iron sulfide precipitation



Bottom water H_2S