Progress and prospects on Ocean Acidification research of the Tropical South Atlantic

Kikuchi, R. K. P
with contribution of BrOA/SOLAS WS2-6 participants

VIRTUTE SPIRITUS

recor
recifes de corais e mudanças globais

inct AmbTropic

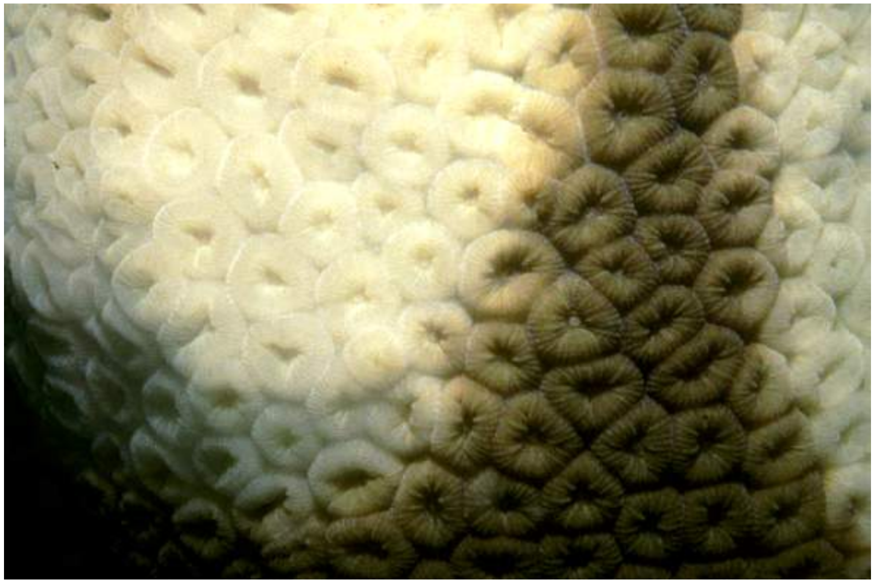
BrOA
BRAZILIAN OCEAN ACIDIFICATION RESEARCH GROUP
Grupo Brasileiro de Pesquisa em Acidificação dos Oceanos

Highlights

- ***OA research is an*** *emerging problem yet to be plainly explored* ***in the national context;***
- *This is an exciting new field for which* ***the pathways that we can follow is not yet settled****;*
- *Individual initiatives might be successful but this is an eminently* ***collaborative field of science*** *(funding and high technology****):***
- ***Br****azilian****O****cean****A****cidificationNetwork has a fundamental role in pushing this field forward;*

Global Climate Changes

- ***Warming***
- ***Sea level rise***



Leo Dutra

coral bleaching

coastal erosion

tribunadonorte.com.br

recently OA

Early facts: Trop. Atl. CO_2 System studies

- Inventory of CO_2 system in the Atlantic (Guber 1998);
- Early 2000's: the role of **Amazon on the sequestration of CO_2** (Ternon *et al*. 2000 and Subramanian *et al.* 2008) and the identification of an **undersaturated zone in** the eastern South Atlantic (Chung *et al*. 2004)
  - Ito *et al*. (2005): seasonality of sink(winter)-source behavior of the Southwestern Atlantic Ocean (not TrAtl)
- Report of **10% reduction on coral growth** during the 90's and early 2000's (Oliveira, 2008)

Large river plumes: Amazonas river

PNAS

Amazon River enhances diazotrophy and carbon sequestration in the tropical North Atlantic Ocean

A. Subramaniam*†, P. L. Yager‡, E. J. Carpenter§, C. Mahaffey¶, K. Björkman‖, S. Cooley‡, A. B. Kustka**, J. P. Montoya††, S. A. Sañudo-Wilhelmy‡‡, R. Shipe§§, and D. G. Capone‡‡

*Lamont–Doherty Earth Observatory, Columbia University, Palisades, NY 10964; ‡Department of Marine Sciences, University of Georgia, Athens, GA 30602; §Romberg Tiburon Center, San Francisco State University, Tiburon, CA 94920; ¶Department of Earth and Ocean Science, University of Liverpool, Liverpool L69 3GP, United Kingdom; ‖Department of Oceanography, SOEST, University of Hawaii, Honolulu, HI 96822; **Institute of Marine and Coastal Sciences, Rutgers, The State University of New Jersey, New Brunswick, NJ 08901; ††School of Biology, Georgia Institute of Technology, Atlanta, GA 30332; ‡‡Wrigley Institute for Environmental Studies and Department of Biological Sciences, University of Southern California, Los Angeles, CA 90089; and §§Department of Ecology and Evolutionary Biology and Institute of the Environment, University of California, Los Angeles, CA 90095

Edited by David M. Karl, University of Hawaii, Honolulu, HI, and approved April 24, 2008 (received for review October 29, 2007)

The fresh water discharged by large rivers such as the Amazon is transported hundreds to thousands of kilometers away from the coast by surface plumes. The nutrients delivered by these river plumes contribute to enhanced primary production in the ocean, and the sinking flux of this new production results in carbon sequestration. Here, we report that the Amazon River plume supports N_2 fixation far from the mouth and provides important pathways for sequestration of atmospheric CO_2 in the western tropical North Atlantic (WTNA). We calculate that the sinking of carbon fixed by diazotrophs in the plume sequesters 1.7 Tmol of C annually, in addition to the sequestration of 0.6 Tmol of C yr^{-1} of the new production supported by NO_3 delivered by the river. These processes revise our current understanding that the tropical North Atlantic is a source of 2.5 Tmol of C to the atmosphere [Mikaloff-Fletcher SE, *et al.* (2007) Inverse estimates of the oceanic sources and sinks of natural CO_2 and the implied oceanic carbon transport. *Global Biogeochem Cycles* 21, doi:10.1029/2006GB002751]. The enhancement of N_2 fixation and consequent C sequestration by tropical rivers appears to be a global phenomenon that is likely to be influenced by anthropogenic activity and climate change.

diatom diazotroph associations | nitrogen fixation | new production | river plumes | *Richelia*

tions studied the plume in the open ocean beyond the shelf. We undertook three field campaigns to study the influence of the Amazon River on the carbon and nitrogen cycles beyond the shelf. Samples at a total of 82 stations in the WTNA in January to February 2001, July to August 2001, and April to May 2003 (Fig. 1 and Table S2) complement earlier studies by examining the region of the plume starting 300 km north of the mouth of the river. We classified the stations into three categories based on sea surface salinity (SSS).¶¶ The "low salinity" group contained all of the stations with SSS <30. Stations that had SSS between 30 and 35 were classified as "mesohaline," whereas those with SSS >35 were classified as "oceanic."

Surface NO_3 concentrations were below detection at most stations, with the highest value of 0.50 μM recorded at the station with the lowest salinity of 24. DeMaster and Pope (7) found when plotting NO_3 vs. soluble reactive phosphorus (SRP) concentrations for samples taken from outside the river mouth and adjacent shelf, the SRP concentration was 0.14 μM at the zero NO_3 intercept, implying that the Amazon is an important source of "excess" SRP (N:P < 16) to the WTNA. Using SRP concentration in the river, Devol (8) calculated that the Amazon contributed ≈30% of global riverine SRP flux to the ocean. This is very likely an underestimate because it does not include the

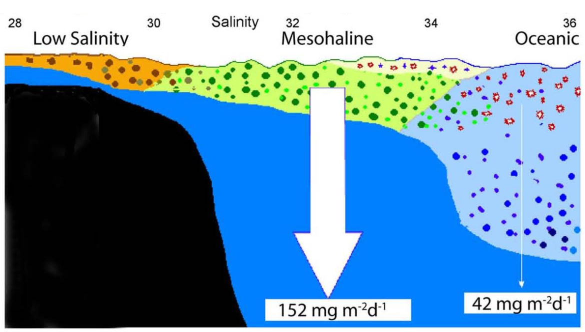
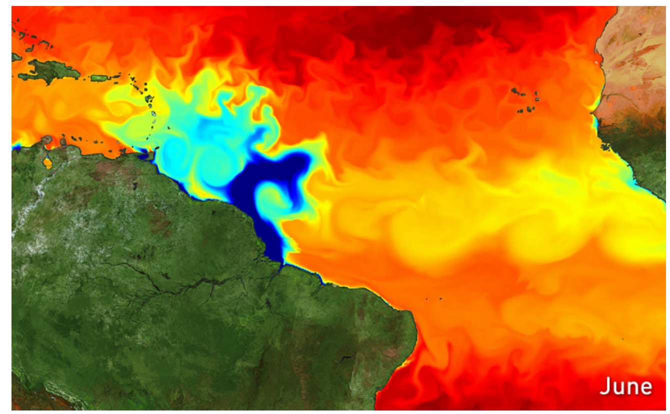
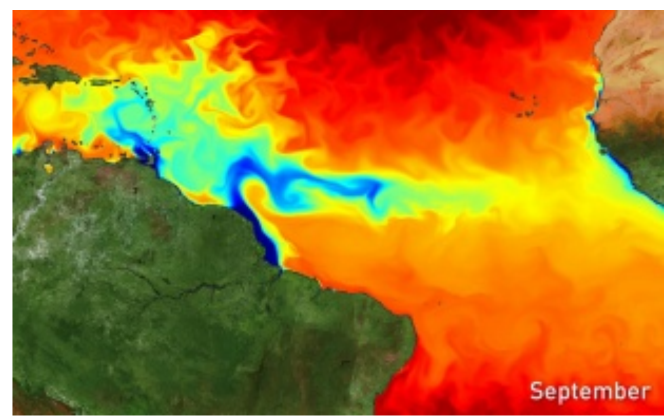


Fig. 3. Changes along the river plume as it moves offshore. (*Top*) Changes in surface nutrient concentrations as a function of salinity for each of the station types; the values and statistics are presented in Table 1. Error bars denote standard error; the thick horizontal line on the *x* axis indicates the mean salinity ±1 S.E. for each group of stations. (*Middle*) Changes in biological response and mass flux from floating sediment traps at 200 m presented as in *A*. (*Bottom*) A schematic of changes along the plume; the arrows showing the mean mass flux for the mesohaline, and oceanic stations. The brown particles represent coastal phytoplankton species; the dark green represents DDA; the red represents *Trichodesmium*; and the blue represents particles typical of oligotrophic oceanic phytoplankton. Phytoplankton chlorophyll, *Trichodesmium*, and *Richelia* concentrations are given in Table 1. Water below the euphotic zone is depicted in solid dark blue, and the 1% light depths are given in Table 1.





MyOcean (2011)

Early facts:
proxies and effects on organisms

- Since about 2005 we are investigating the potential of (endemic) coral skeletons as natural archives of *proxies*;

Journal of Experimental Marine Biology and Ecology 449 (2013) 207–214

Contents lists available at ScienceDirect

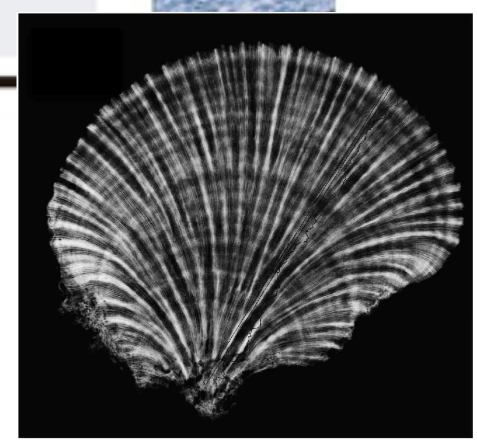
Journal of Experimental Marine Biology and Ecology

journal homepage: www.elsevier.com/locate/jembe

Density banding pattern of the south western Atlantic coral *Mussismilia braziliensis*

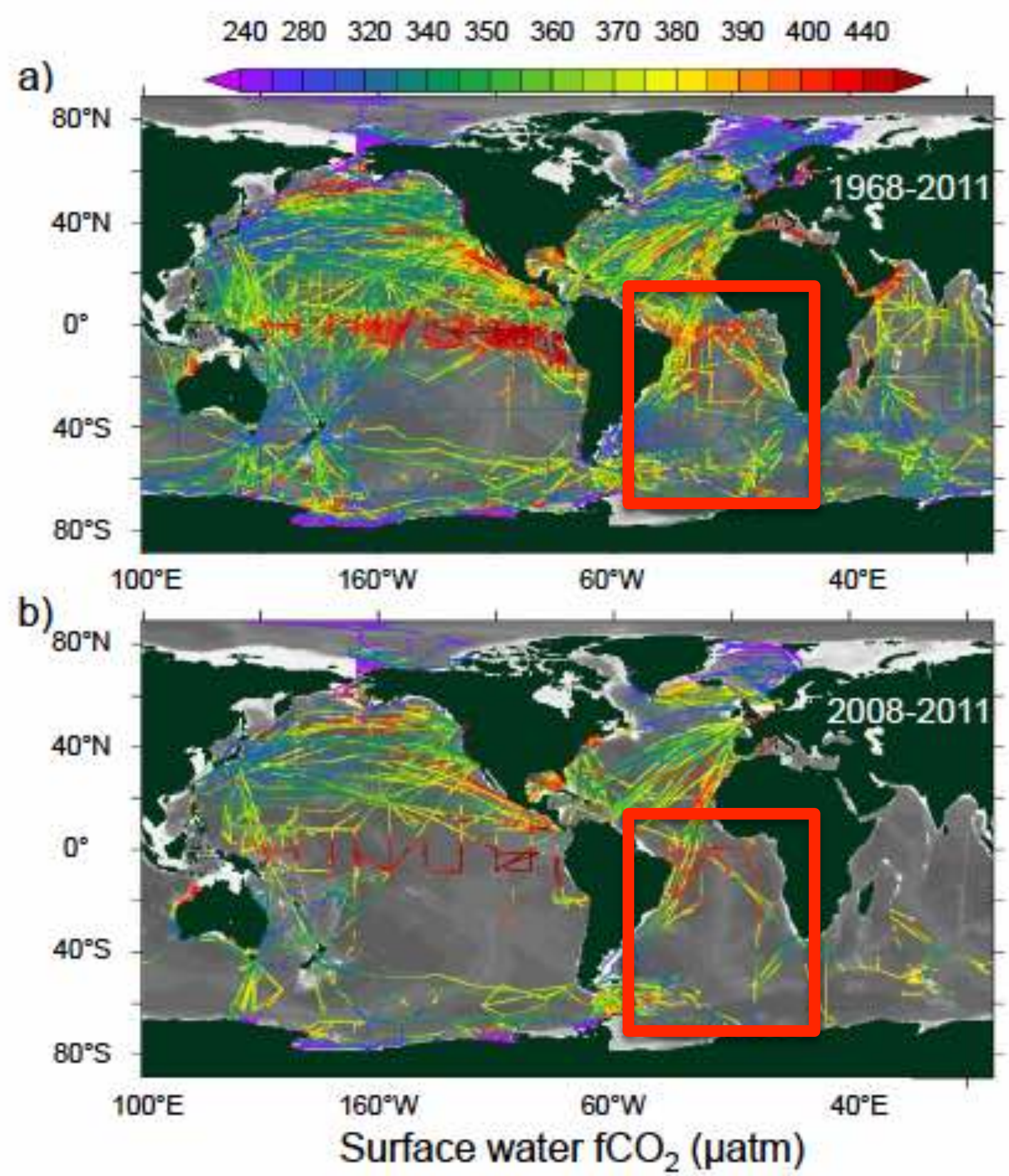
Ruy K.P. Kikuchi *, Marilia D.M. Oliveira, Zelinda M.A.N. Leão

Laboratory of Coral Reefs and Global Changes Studies – RECOR, IGEO-UFBA, Rua Barão de Jeremoabo, s/n, Ondina, CEP 40170-115 Salvador, BA, Brazil



Early facts:

- by 2010 on, some papers by Lefèbre and co-workers detail CO_2 fluxes on the Equatorial region;
- Early statements (speculative) of the possible impacts of OA on rhodoliths beds East shelf of Brazil (Amado-Filho *et al.* 2012);



Milestones:

- 2009 - National Institute of Science and Technology for the Global Changes (**INCT MCG/Rede Clima**):
  - Coastal Zone Working Group: Initial attempts to build a small scale system to test the effect of *p*CO2 increase in calcifying corals began in 2011; Blue Carbon
- mid 2012 - National Institute of Science and Technology for Tropical Marine Environment (**inctAmbTropic**)
  - basin scale CO_2 system studies; continuing of efforts to test warming + pCO_2 on corals/CCA/sediments
- **Dec 2012 - Brazilian OA network created**

www.broa.furg.br

Working Packages of the INCT-AmbTropic

(www.inctambtropic.org) Coordinator: José M. L. Dominguez

inct AmbTropic

WP1: Coastal Zone

WG.1: Responses of the Coastline

WG1.2: Fluvial Plumes

WG1.3: Reefs and Coralline Ecosystems

WG1.4: Mangroves

WG1.5: Markers for Environmental Impact

WP2: Continental Shelf

WG2.1: Geodiversity, Biodiversity of Substrates

WG2.2: Trophic Diversity and Structure of Pelagic Environment

WG2.3: Genomics, Proteomics & Biodiversity

WG2.4: Bioprospection of Natural Products from Marine Organisms

WP3: Ocean

WG3.1: Ocean-Atmosphere Interaction, Climatic Variab. and Predictability in N-NE Brazil and Trop. Atl.

WG3.2: Biogeochemical Cycles, CO_2 Fluxes and Acidification of the Trop. Atl.

WG3.3: Living Resources in the TA and Oceanic Islands

Milestone:
Brazilian OA network

Mission:

Create a network of scientists working on Ocean Acidification in Brazil, concomitant to establishing **LONG TERM OBSERVATIONS of CO_2** - related parameters in marine ecosystems.

Objectives:

Identify and integrate the Brazilian researchers through a **cooperative inertdisciplinary network**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2nd Report of the Brazilian Ocean Acidification Research Group

based on the discussions occurred during the 3rd Brazilian Workshop on Climate Changes in Coastal Zones, held in Florianopolis (SC, Brazil) in December 2013.

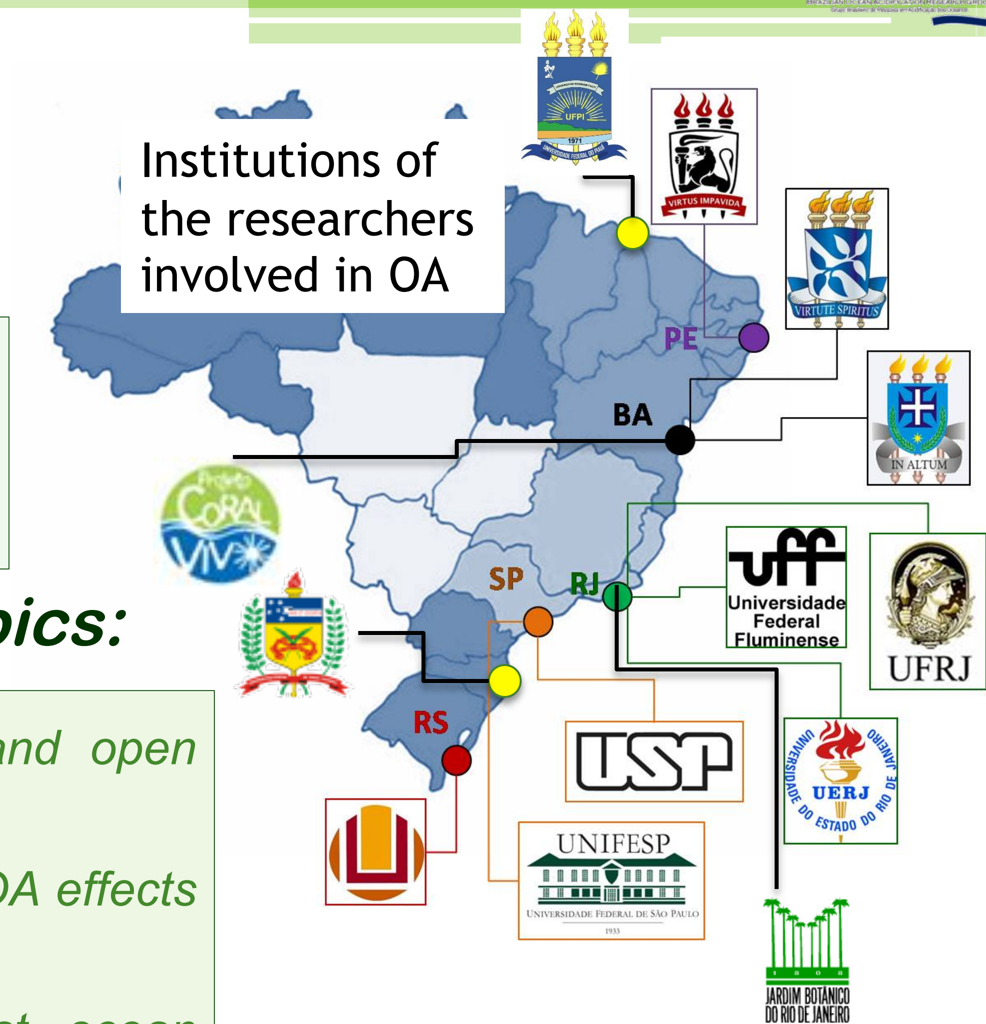
Rodrigo Kerr
Leticia Cotrim da Cunha
Rosane Gonçalves Ito

May 2014

www.broa.furg.br

Where is the infrastructure ?

13 Institutions
23 Laboratories
2 mesocosm facilities
42 Researchers



BrOA's main research topics:

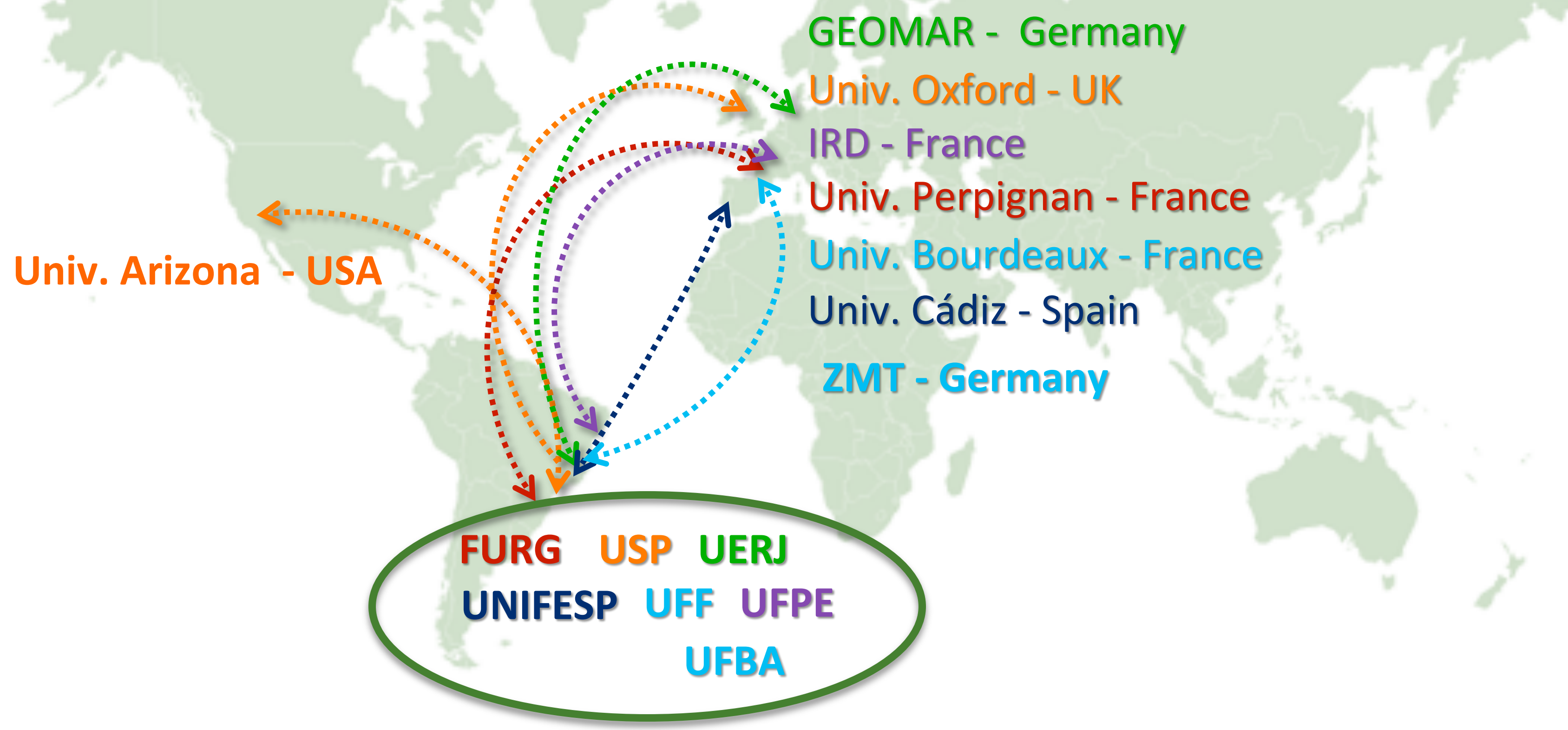
- ✓ *Marine biogeochemistry (coastal and open ocean areas)*
- ✓ *Response of marine organisms to OA effects (bio-assays)*
- ✓ *Paleoceanography proxies to past ocean acidification events and → carbonate system*
- ✓ *Biogeochemistry modeling*
- ✓ *Physical and biogeochemical processes controlling sea ↔ air CO_2 fluxes*

Diretório dos Grupos de Pesquisa no Brasil Lattes

Certified by CNPq

International Colaborations... individual.

FURG – Univ. Perpignan/France
USP – Univ. Oxford/UK & Univ. Arizona/USA
UERJ – GEOMAR/Germany
UNIFESP – Univ. Cádiz/Spain
UFF – Univ. Bourdeaux/France
UFPE – IRD/France
UFBA – ZMT/Germany



OA activities during the last two years on the Tropical Atlantic (2013 and 2014)

From estuaries/coastal to the ocean basin…

…from laboratories to the field.

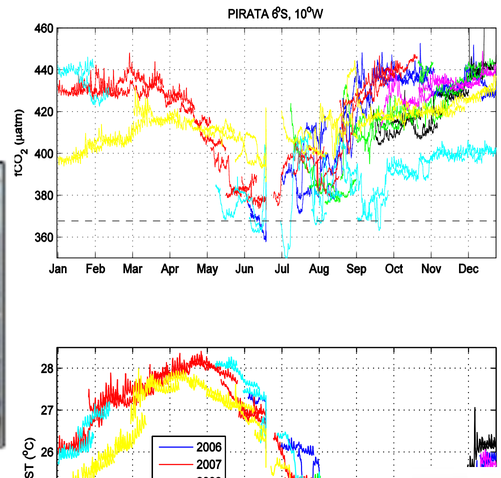
PIRATA

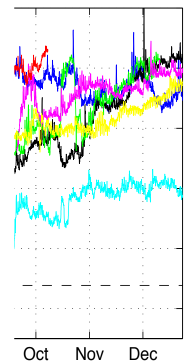
pCO_2/O_2 continuous measurements

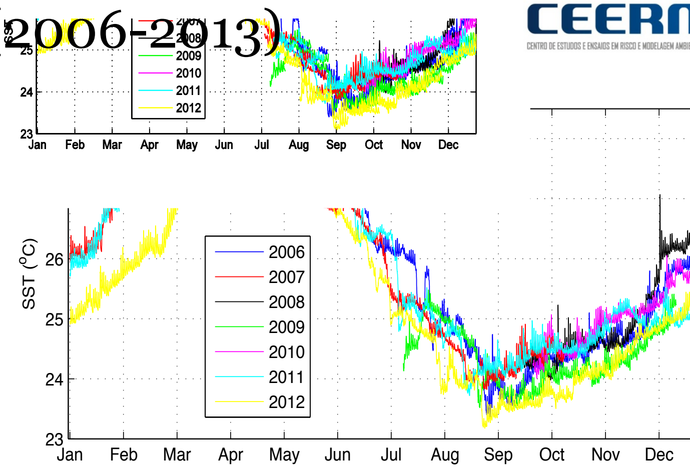
Araujo and Lefèbvre

UFPE

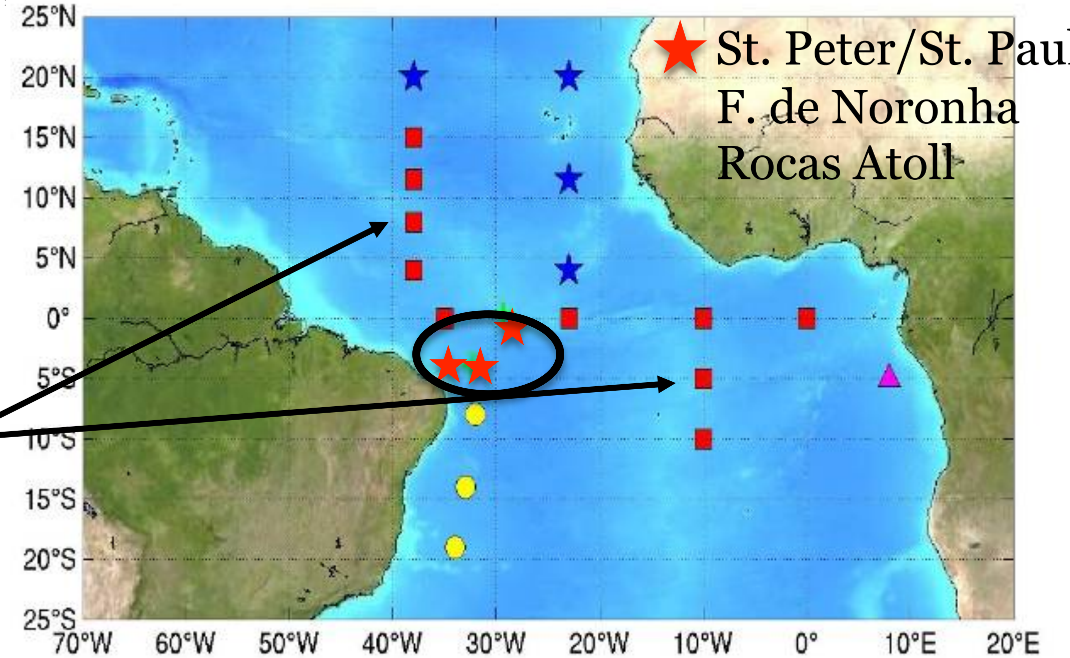
6°S10°W (2006-2013)







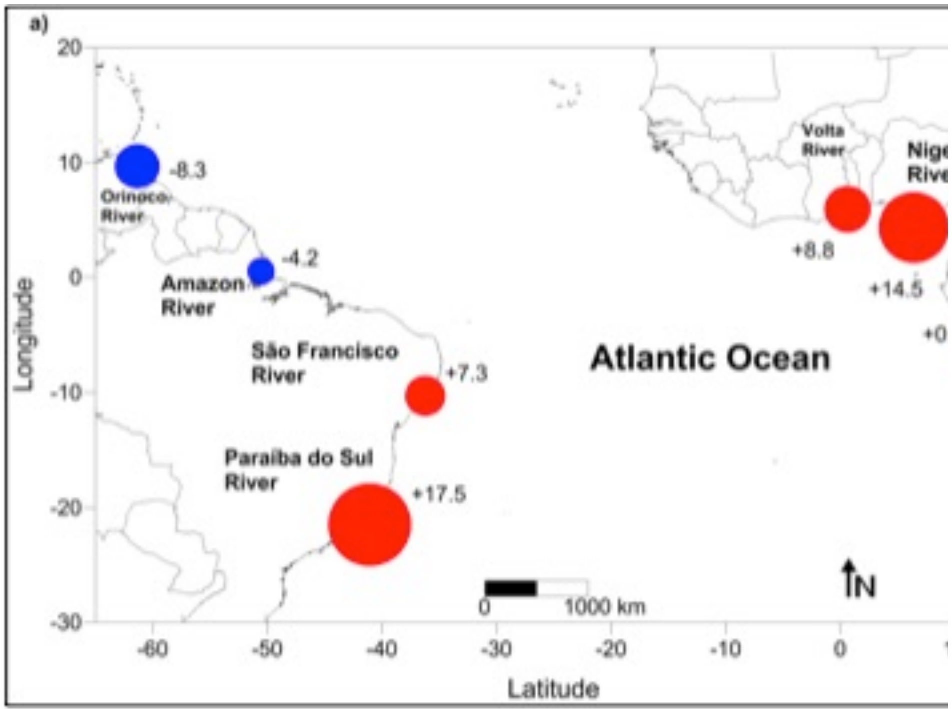
8°N38°W (2008-2013)



Advances in flux estimation

Coastal seas and estuarine regions …

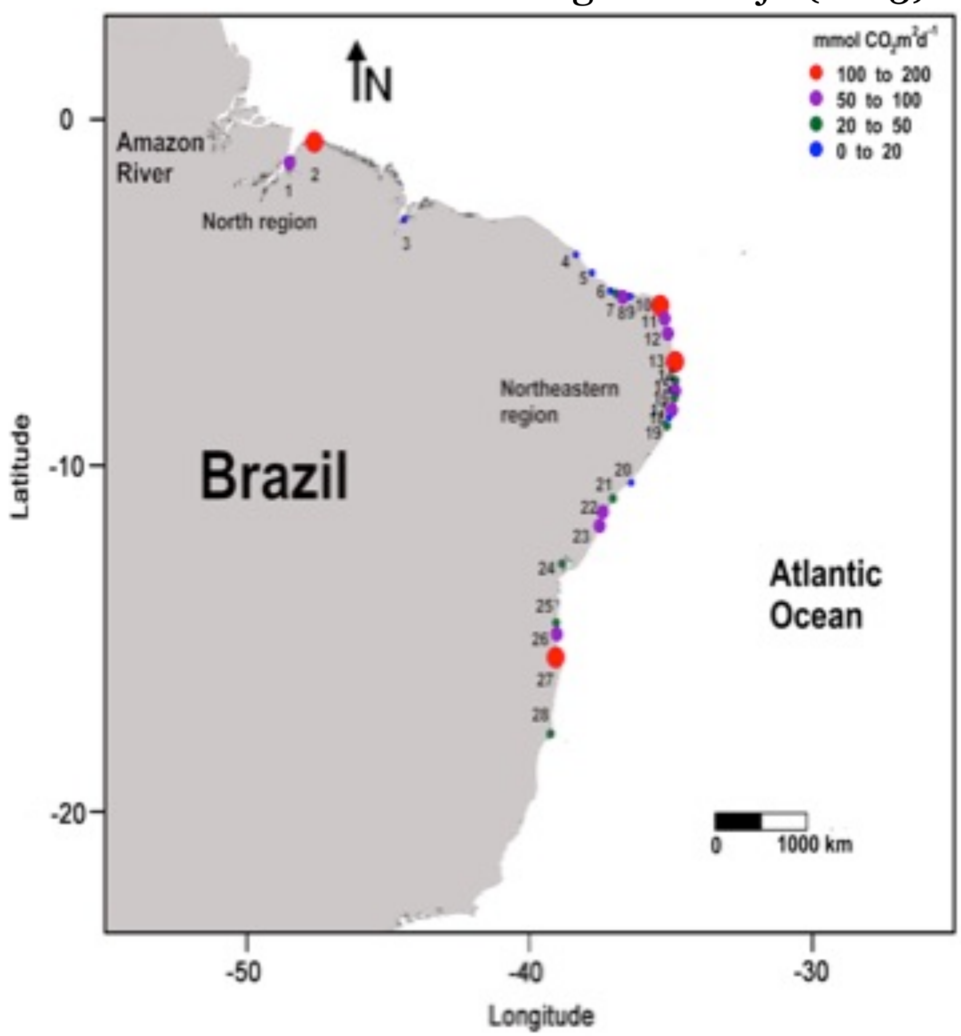
CO_2 flux (mmol C m^{-2} day^{-1})



Red circles (+) source of CO_2 for the atmosphere.
Blue circles (-) atmospheric CO_2 sinks.

Araujo et al. (2013)

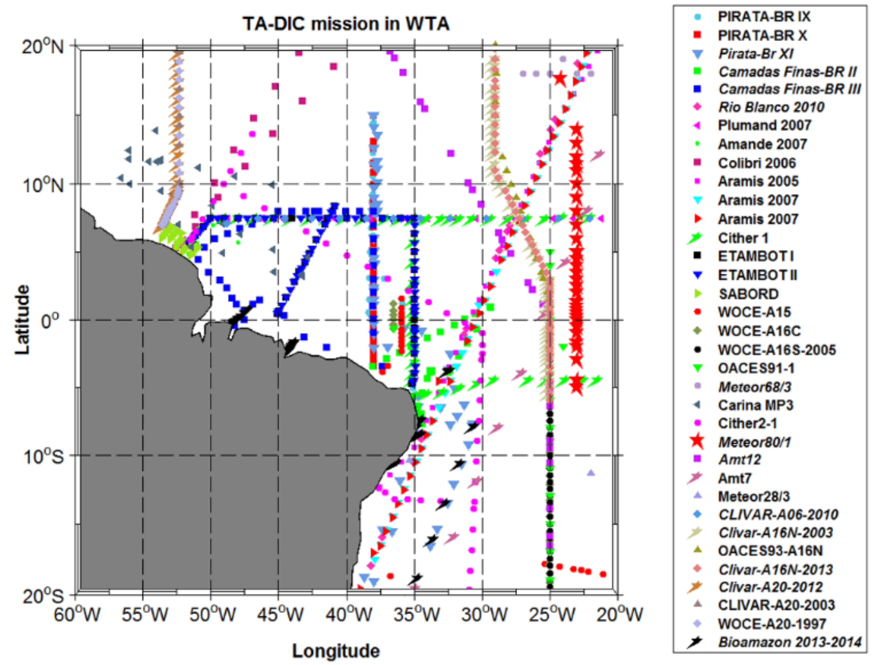
Noriega & Araujo (2013)

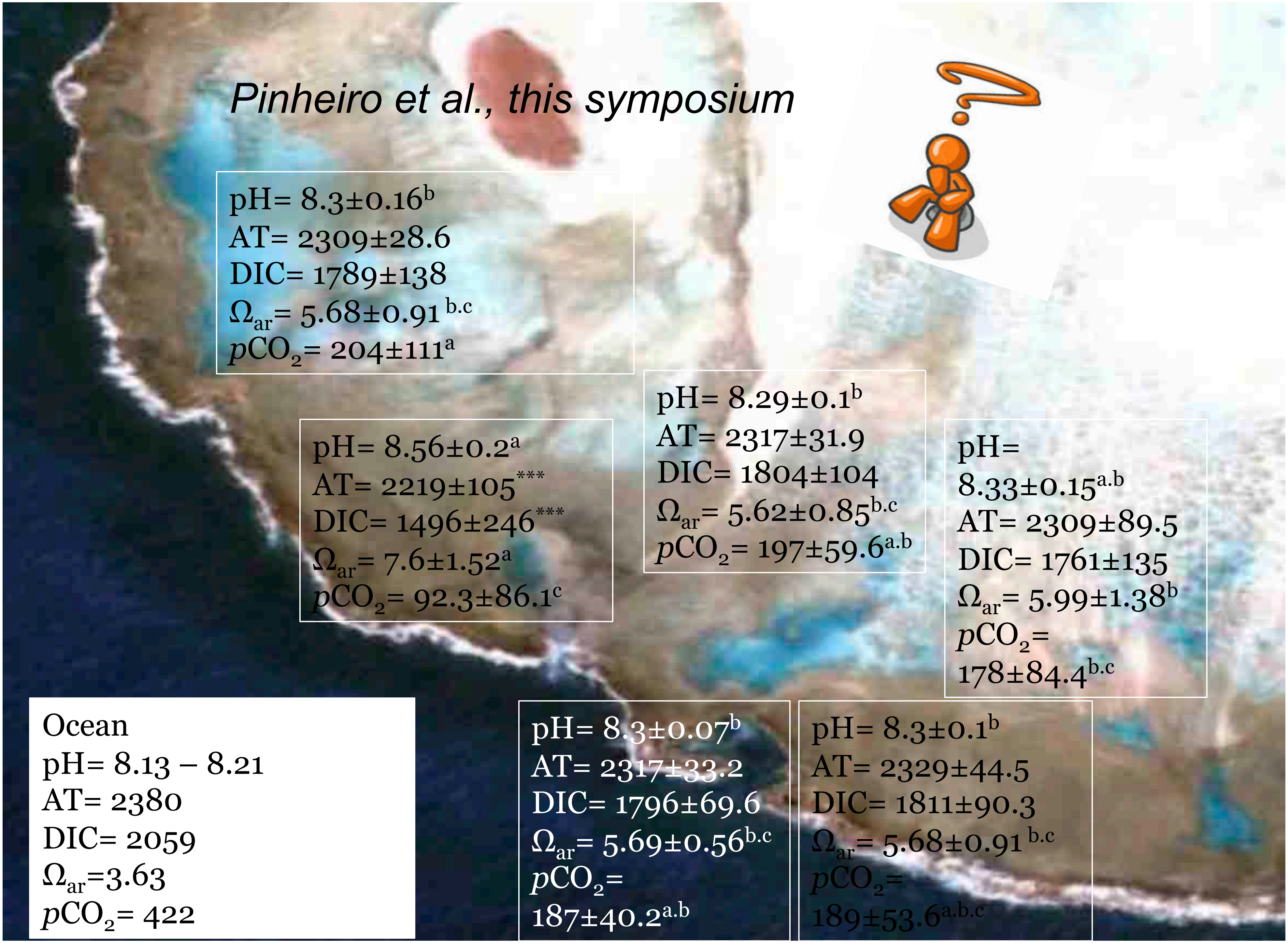


Bonou et al. **this symposium**

Distribution of CO2 parameters in Western Tropical Atlantic Ocean

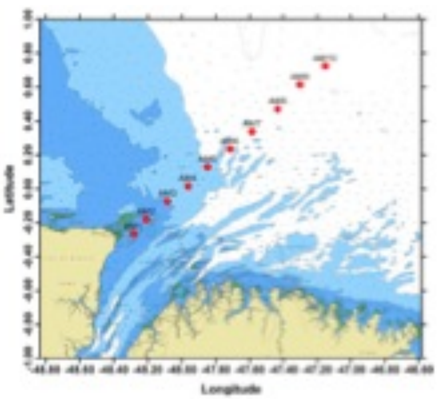
✓ **New relationship was determined for CT** using the SSS and time factor (year);

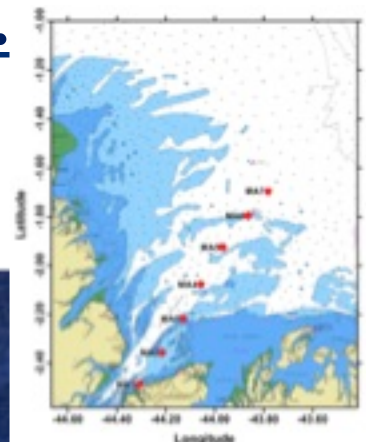


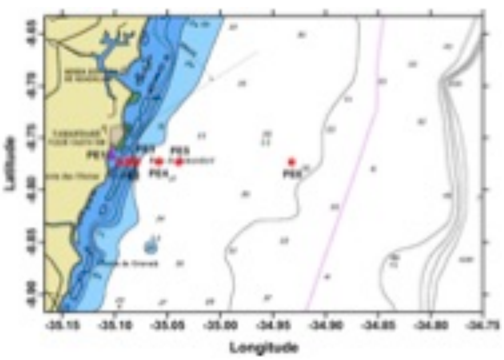

Pinheiro et al., this symposium
pH= 8.3±0.16[b]
AT= 2309±28.6
DIC= 1789±138
Ω_{ar}= 5.68±0.91 [b.c]
pCO_2= 204±111[a]
pH= 8.56±0.2[a]
AT= 2219±105***
DIC= 1496±246***
Ω_{ar}= 7.6±1.52[a]
pCO_2= 92.3±86.1[c]
pH= 8.29±0.1[b]
AT= 2317±31.9
DIC= 1804±104
Ω_{ar}= 5.62±0.85[b.c]
pCO_2= 197±59.6[a.b]
pH= 8.33±0.15[a.b]
AT= 2309±89.5
DIC= 1761±135
Ω_{ar}= 5.99±1.38[b]
pCO_2= 178±84.4[b.c]
Ocean
pH= 8.13 – 8.21
AT= 2380
DIC= 2059
Ω_{ar}=3.63
pCO_2= 422
pH= 8.3±0.07[b]
AT= 2317±33.2
DIC= 1796±69.6
Ω_{ar}= 5.69±0.56[b.c]
pCO_2= 187±40.2[a.b]
pH= 8.3±0.1[b]
AT= 2329±44.5
DIC= 1811±90.3
Ω_{ar}= 5.68±0.91 [b.c]
pCO_2= 189±53.6[a.b.c]

Bimonthly water sampling (pH/DIC/TA) in different cross-shelf transects along the North-Northeastern Brazilian coast, from the Amazon River (equator) to the São Francisco River (10ºS).

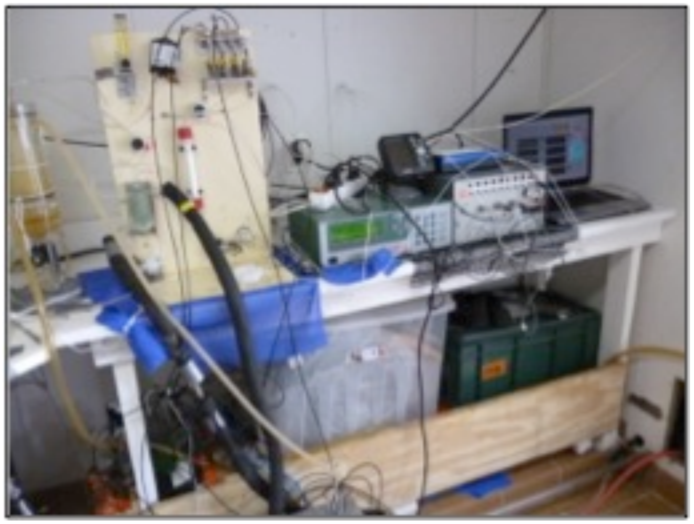
Since April 2013 - …







u-CO_2 equipament
on bord NHo. Cruzeiro do Sul
(Oceanic islands 2012)



New u-CO_2 equipament
DOCEAN/UFPE
(operacional since jan./2014)

Souza et al. **and** *Kikuchi et al*.

Fluxes of carbon and nutrients in the Cachoeira River estuary, Ilheus, Bahia – FAPESB/CNPq (2013 – 2016)

Effects of pCO_2 on metabolism and carbonate dissolution by epi and endolithic communities– UESC (2014 – 2016)

Contents lists available at ScienceDirect

Estuarine, Coastal and Shelf Science

journal homepage: www.elsevier.com/locate/ecss

Net ecosystem production, calcification and CO_2 fluxes on a reef flat in Northeastern Brazil

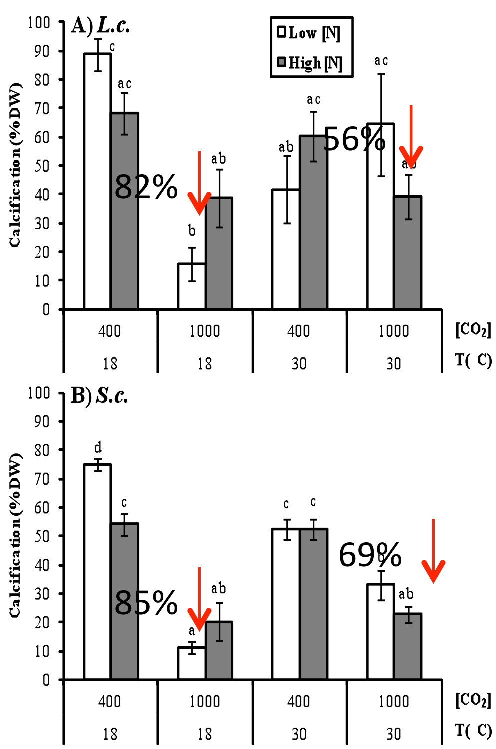
Cybelle M. Longhini [a], Marcelo F.L. Souza [b,*], Ananda M. Silva [a]

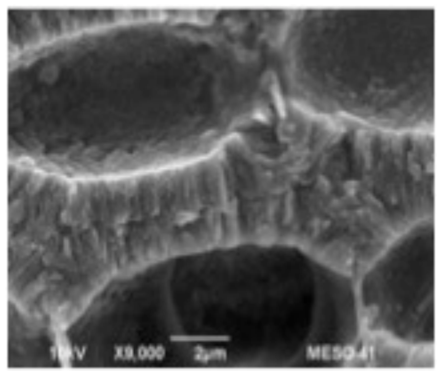
Residual circulation and dynamics of suspended and organic matter in the Todos os Santos Bay – FAPESB (2013 – 2015)

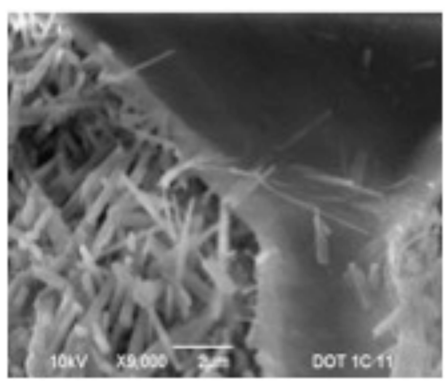
Effects of interaction of acidification and temperature rise on the calcification of corals and crustose coraline algae
CNPq (2013-2015)

Community/organismal level

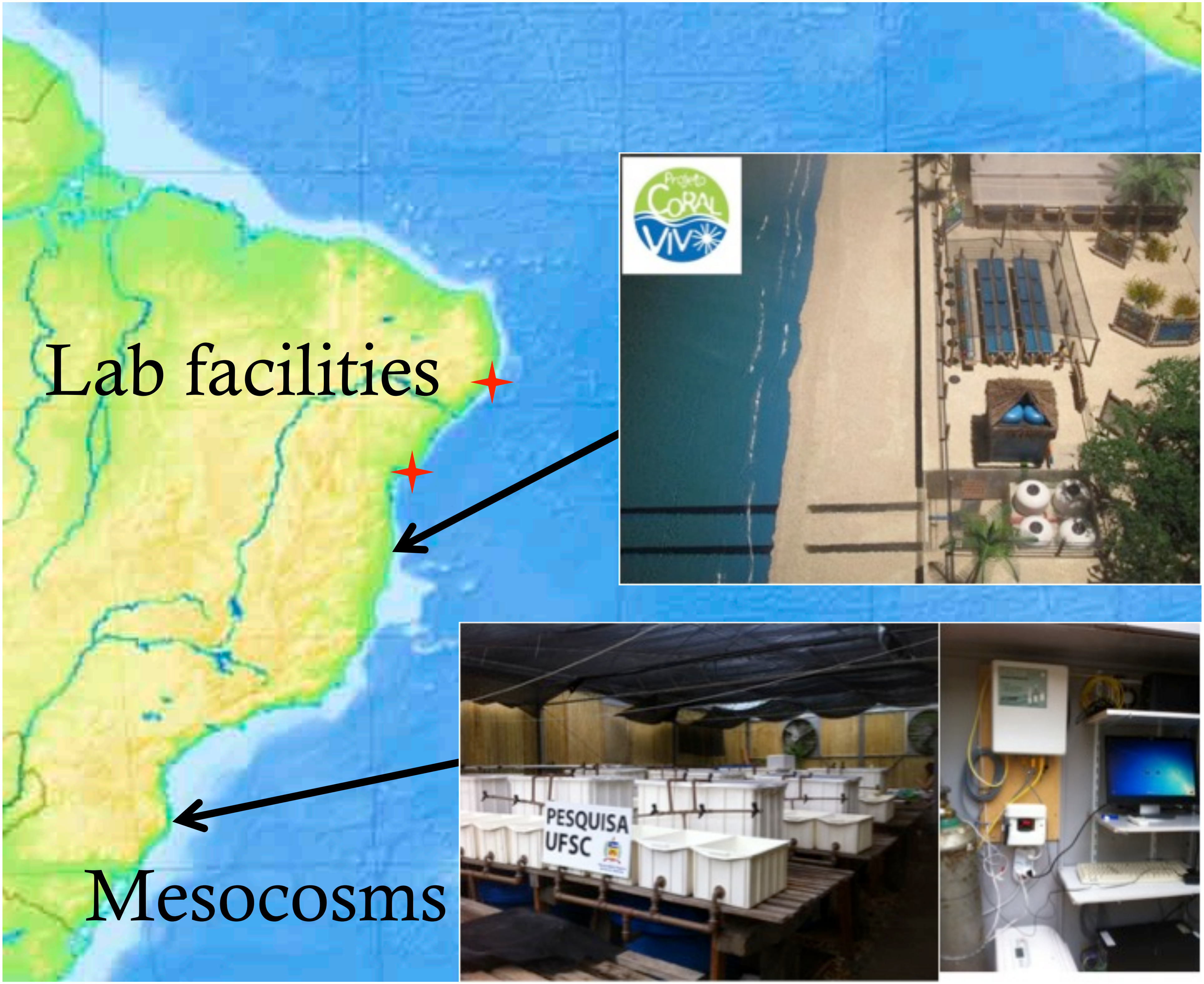
Sarmento et al. 2015a and b (this symposium): increase of meio-fauna invertebrates followed the decrease of pH







Horta 2015 (this symposium): similar organisms may respond differently to a combination of factors (pH and Nutrients); reduction of pH leads to a decrease in photosynthetic efficiency in CCA


Lab facilities
Projeto
CORAL
VIVO
Mesocosms
PESQUISA
UFSC

Paleoceanography and Paleoclimatology Laborator

Research area:

Evaluation of proxies for marine carbonate system

Researchers:

Dr. Adriana Rodrigues Perretti

Prof. Dr. Cristiano Mazur Chiessi

Present project:

Evaluation of marine carbonate dissolution proxies on a low carbonate ion saturation environment

Partnerships stablished

- Recent records (coral):

Ruy Kikuchi (UFBA - BR)

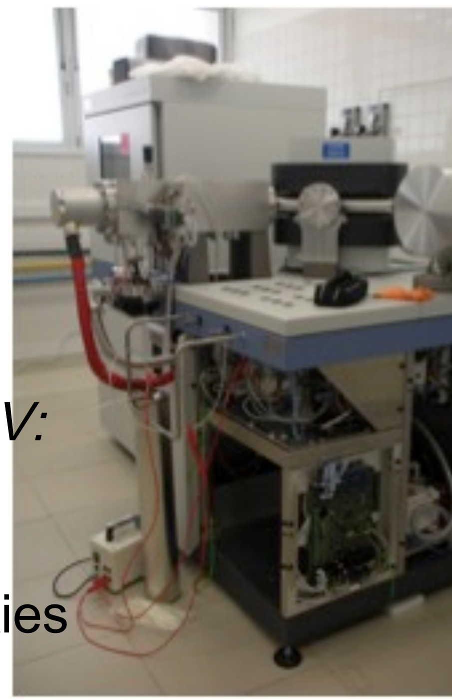
Julia Cole (University of Arizona – USA

- Element/Ca proxies (multiproxy study):

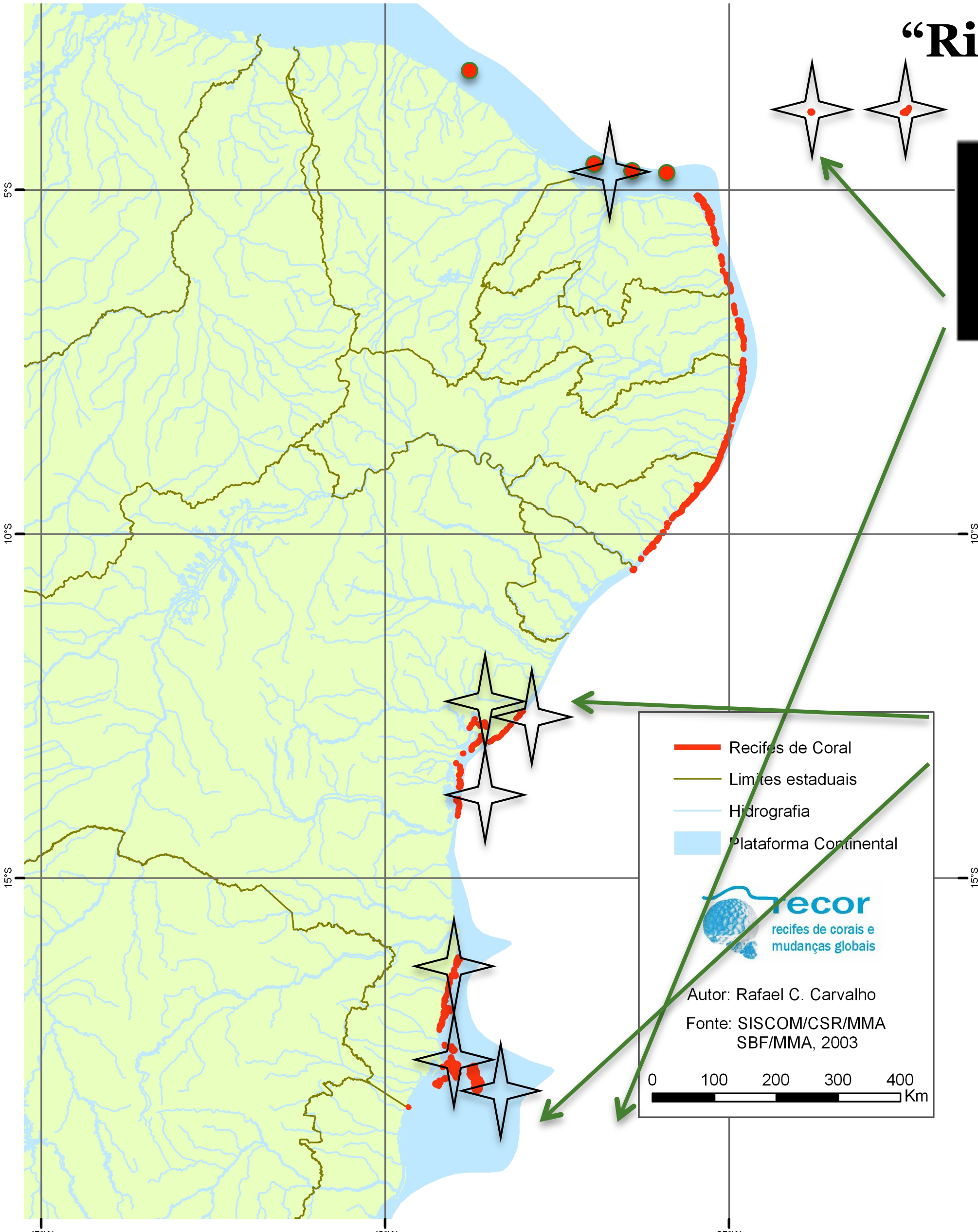
Ros Rickaby (University of Oxford – UK)

Instalation of mass spectrometer MAT 253 with Kiel IV:

Will allow the analysis of stable isotopes ($\delta^{18}O$ and $\delta^{13}C$), on small carbonate samples (foraminifera and corals), usedto reconstruct the environmental properties of past ocean

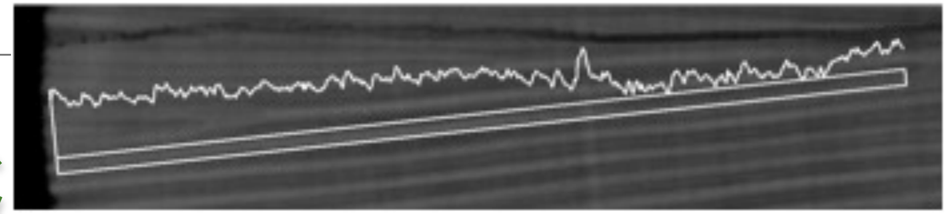


Coral reefs in Western South Atlantic

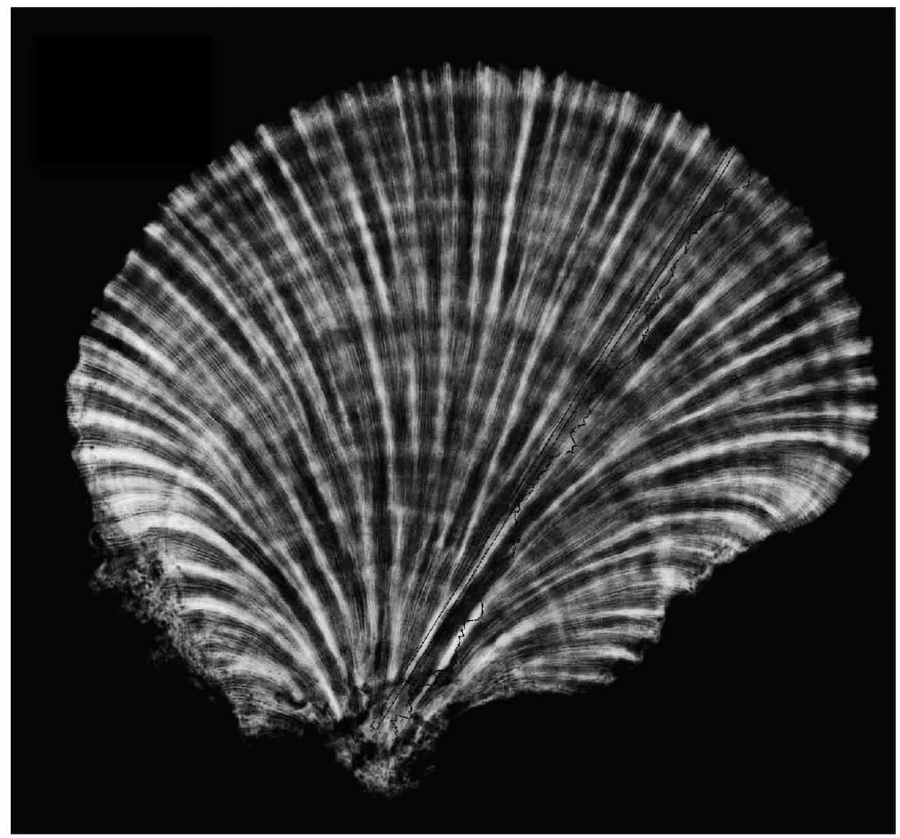


"Rithms in the blue"

Siderastrea stellata

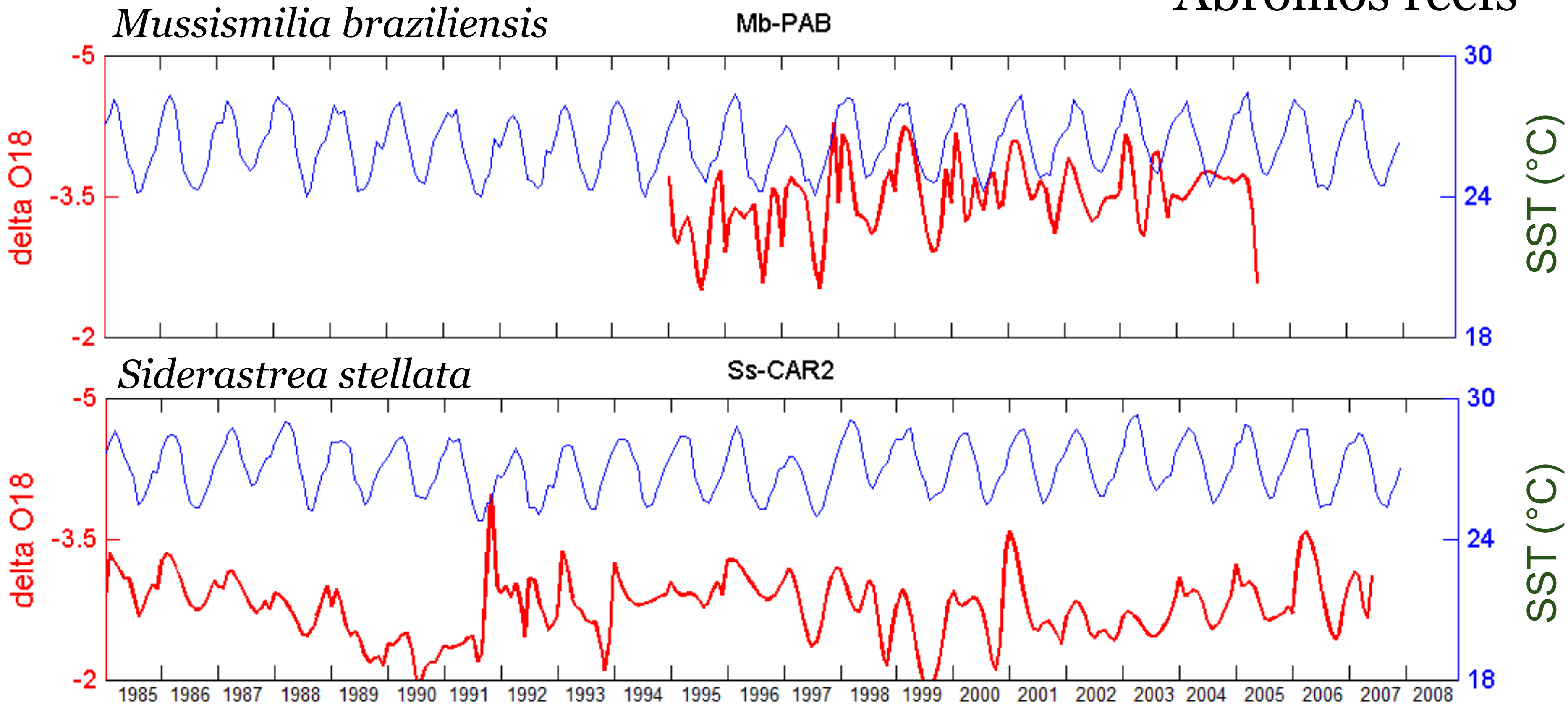


Mussismilia braziliensis



$\delta^{18}O$ X SST

Abrolhos reefs

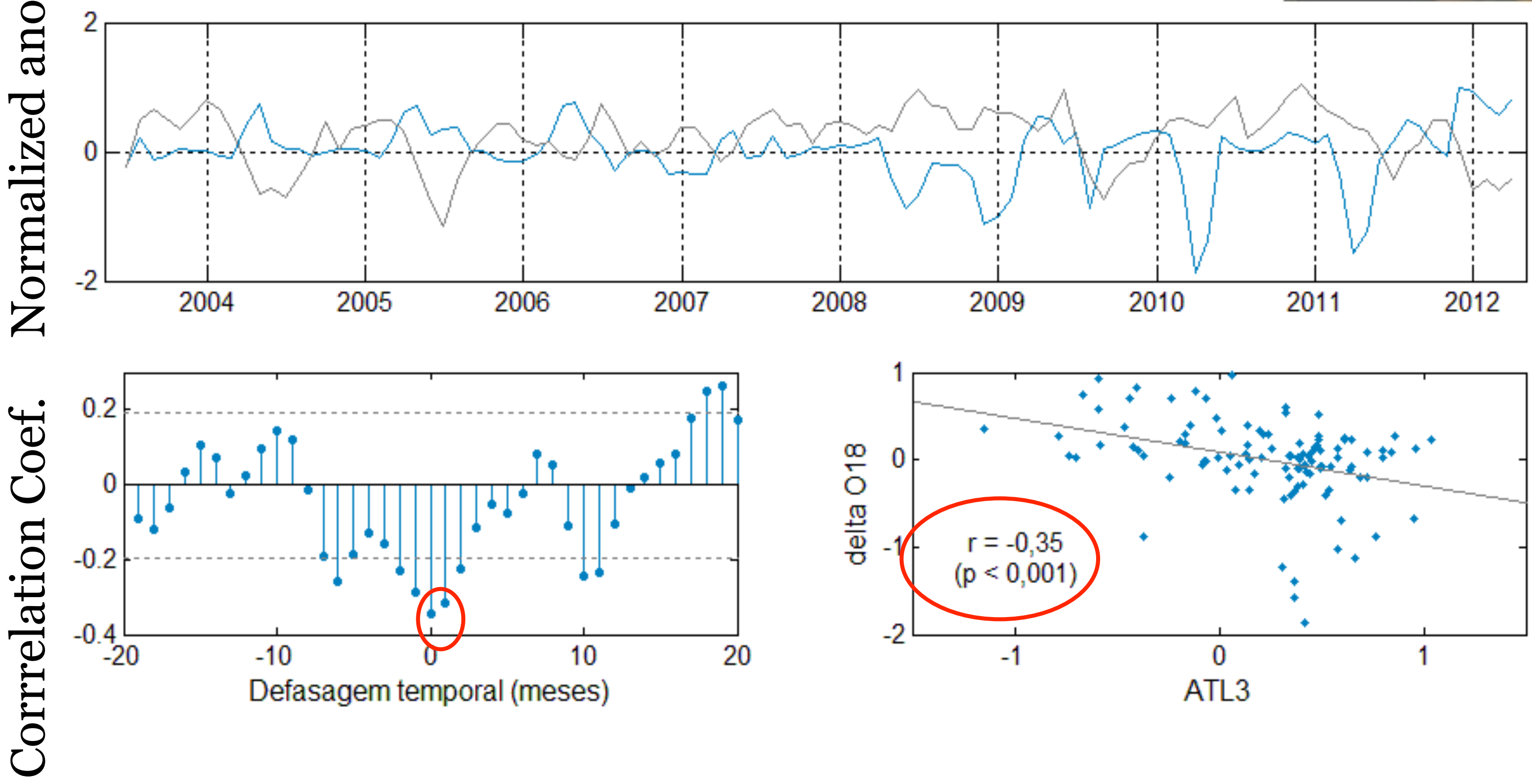


Todos os Santos Bay reefs

Domingues (2009)

Rocas atoll

- $\delta^{18}O$ x Equatorial mode



Yes: the Equatorial Mode inprint is in the coral geochemistry of *Porites*

Prospects:

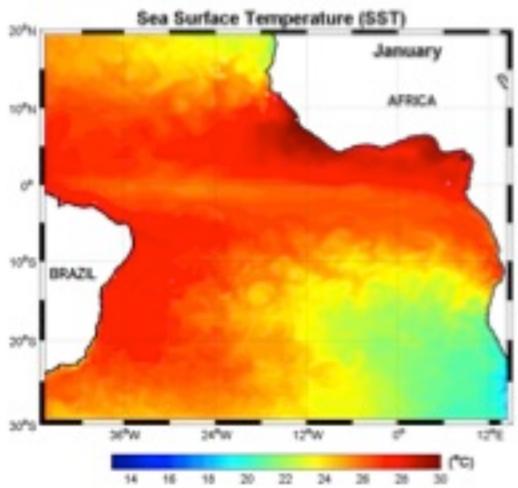
- Organizational:
  - identify the research groups dedicated to the theme of OA;
  - enhance synergy between these groups
- Scientific
  - identify research priorities, benefitting from experience from the more advanced groups
  - identify economic problems associated with OA
  - share infrastructure

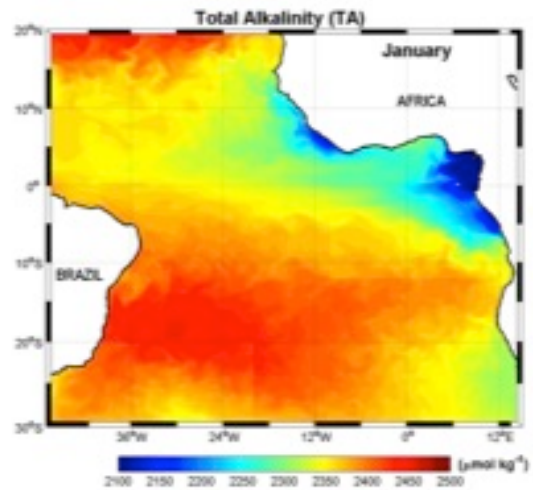
Prospects

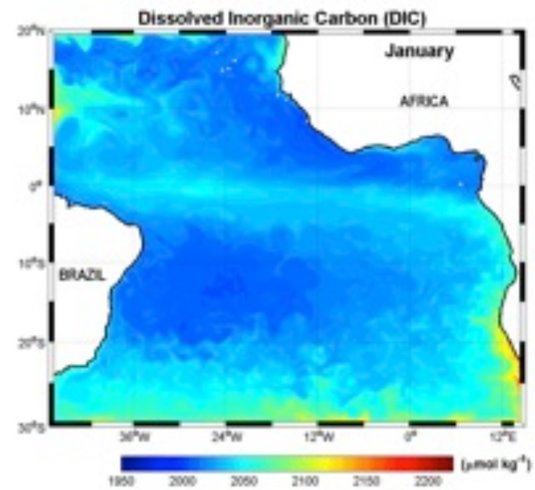
- *Modeling*
  - *of future state of CO_2 system scenarios;*
  - *enhance resolution of models (meso to submesoscale)*
- *Select case studies of each coastal ecosystem to understand the effect of OA*
- *Produce time series (buoy) in strategic sites;*
- *Experiments: effects on selected organisms/habitats;*
- *Calibrate proxies (corals)*

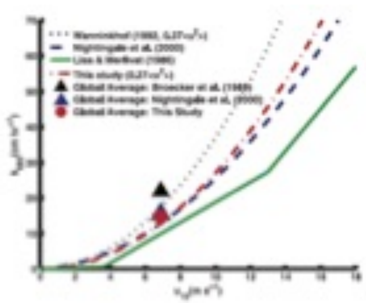
WP3.2 Mathematical modeling: Large scale (TrAtl)

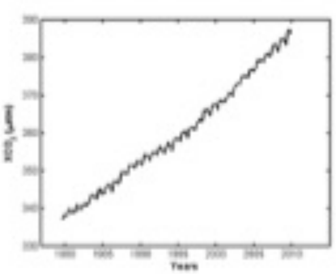
CO2 Fluxes Forecast (2012-2100)







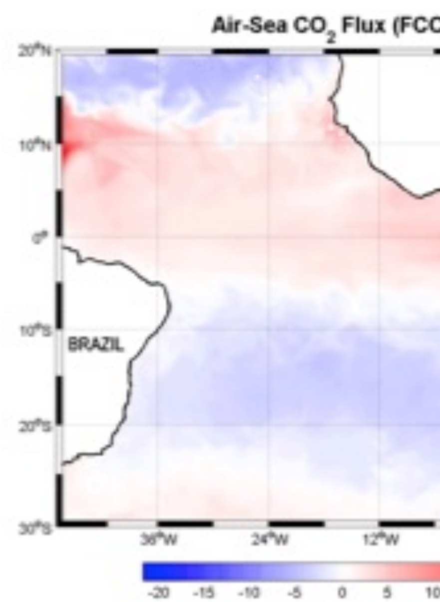




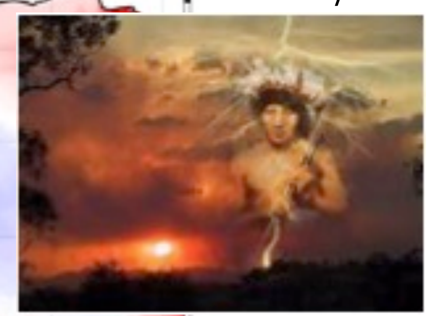
$KCO_2 = g_1(u^2_{10}, Sc)$ $pCO_{2ATM} = g_4(PH_2O, XCO_2)$

$pCO_{2SEA} = g_3(SST, SSS, TA, DIC)$

$FCO_2 = KCO_2\ \alpha\ (pCO_{2SEA} - pCO_{2ATM})$



CPTEC/INPE



Thank you!

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