From open ocean to coastal zones: ocean acidification and its impacts”

Prof. Dr. Leticia Cotrim da Cunha
(Faculdade de Oceanografia, Universidade do Estado do Rio de Janeiro – UERJ)

German-Brazilian Lectures on Climate Change Effects on the Oceans

July 9th 2014

Museu Naval – Rio de Janeiro

Centro Alemão de Ciência e Inovação – São Paulo
X 1
Alemanha
País de Ideias

future ocean
KIEL MARINE SCIENCES

Special thanks to
Rodrigo Kerr
Bárbara Pinheiro

UERJ
UNIVERSIDADE DO ESTADO DO RIO DE JANEIRO

FACULDADE DE OCEANOGRAFIA

LABOQUI
Laboratório de Oceanografia Química UERJ

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

- **Facts about climate change and anthropogenic CO_2 emissions**

- **What exactly is "ocean acidification" from a chemical point of view?**

- **Are there other forcings for changes in seawater pH?**

- **OA effects on open ocean areas**

Things we know
Predictions

- **OA effects on coastal areas**

Why are coastal areas so complex?
Is it possible to make predictions for the coastal area?

- **What is currently going on in OA research Brazil?**

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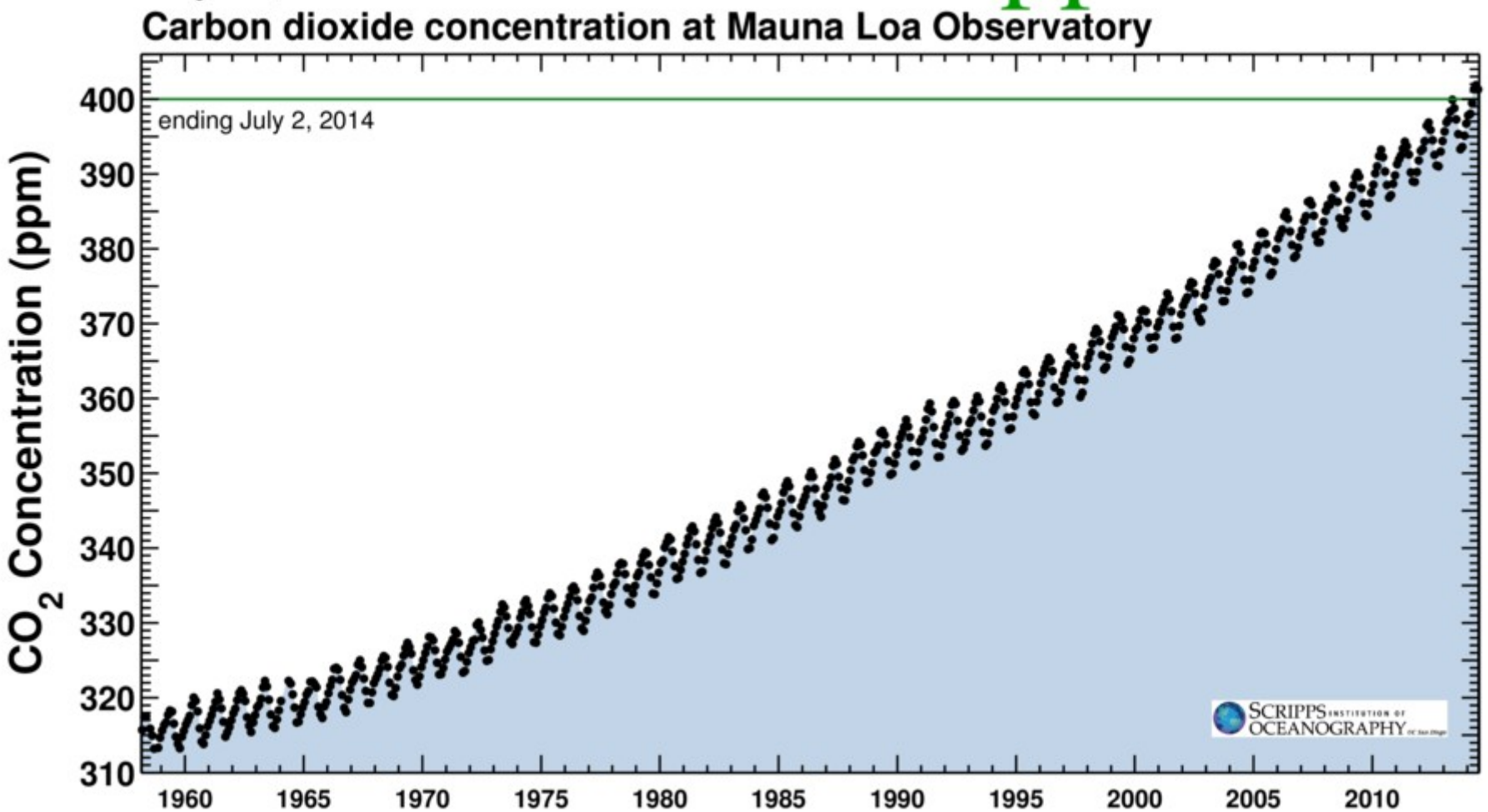
Latest CO_2 reading
July 02, 2014

400.40 ppm



https://scripps.ucsd.edu/programs/keelingcurve/

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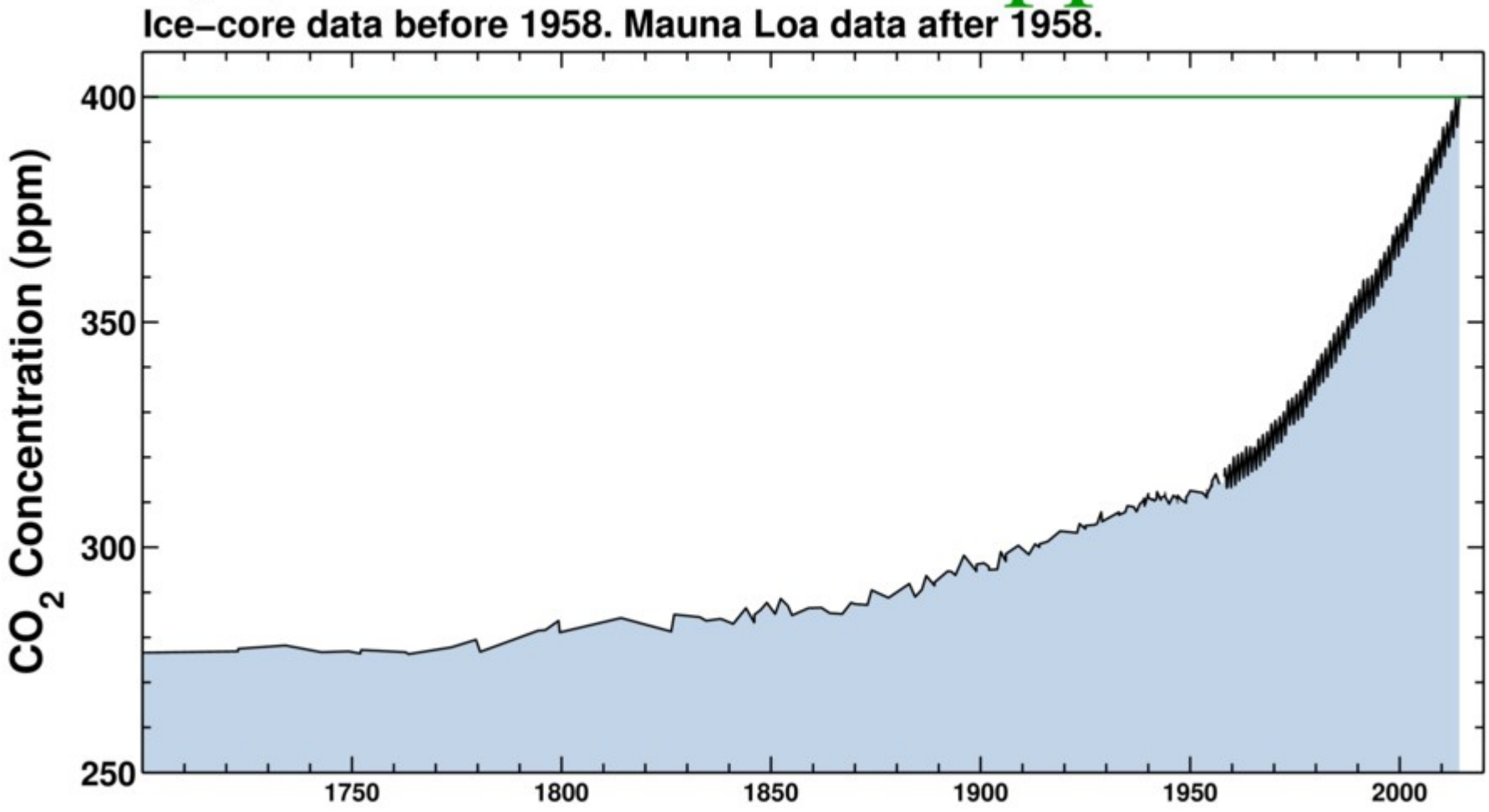
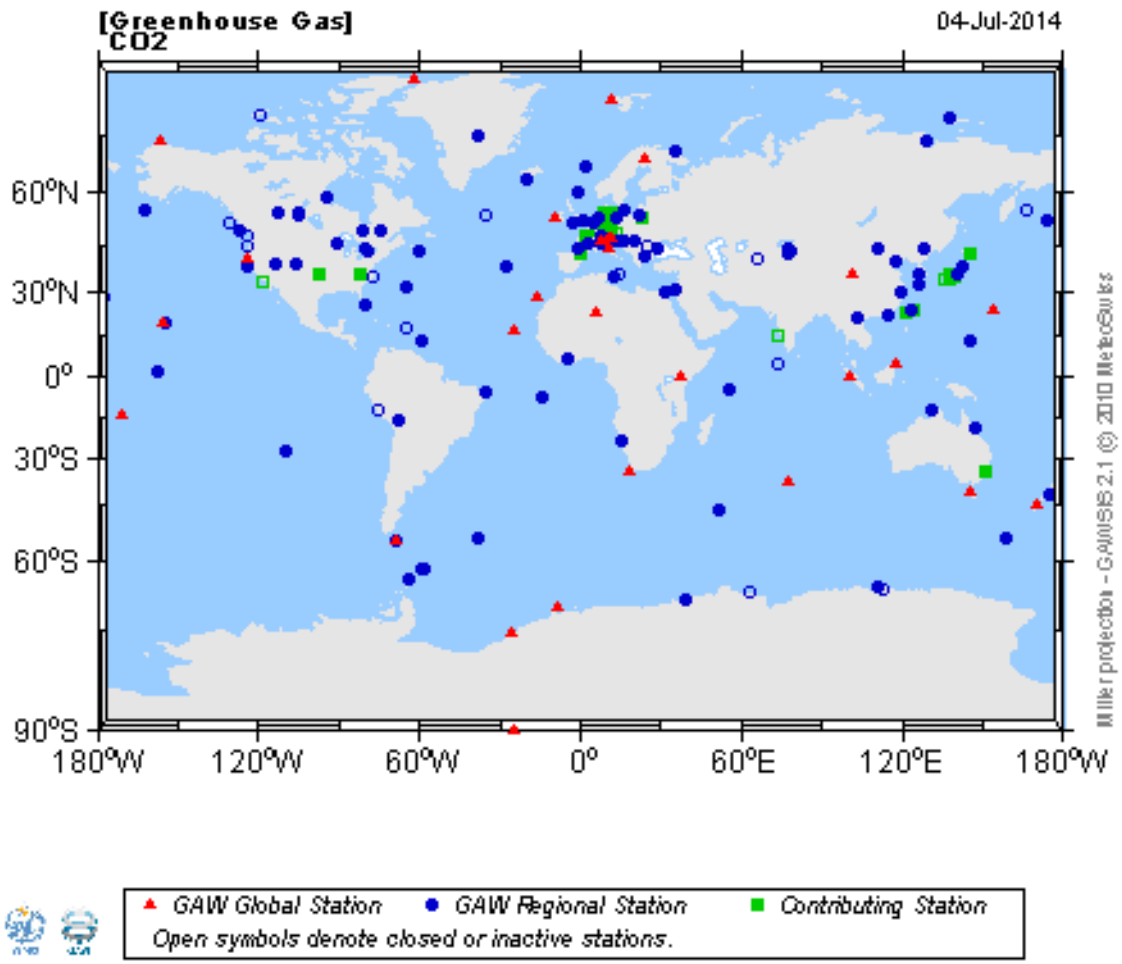


Mauna Loa is not the only atmospheric CO_2 observatory!



http://gaw.empa.ch/gawsis/

Fate of Anthropogenic CO_2 Emissions (2003-2012 average)

8.6 ± 0.4 GtC/yr 92%

0.8 ± 0.5 GtC/yr 8%

+

4.3±0.1 GtC/yr
45%

2.6 ± 0.5 GtC/yr
27%

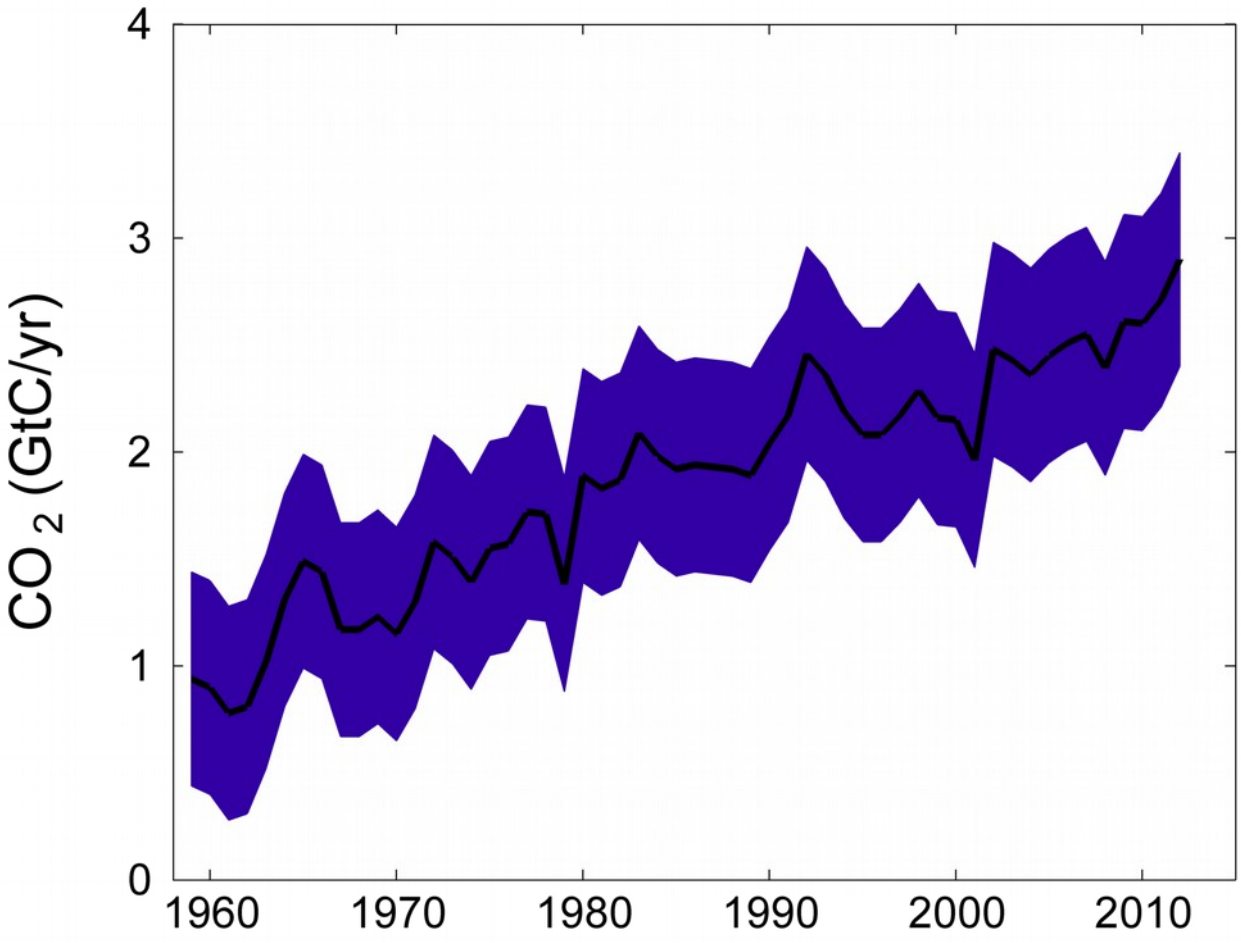
2.6 ± 0.8 GtC/yr
27%

Calculated as the residual
of all other flux components

Source: Le Quéré et al 2013; CDIAC Data; Global Carbon Project 2013 http://www.globalcarbonproject.org

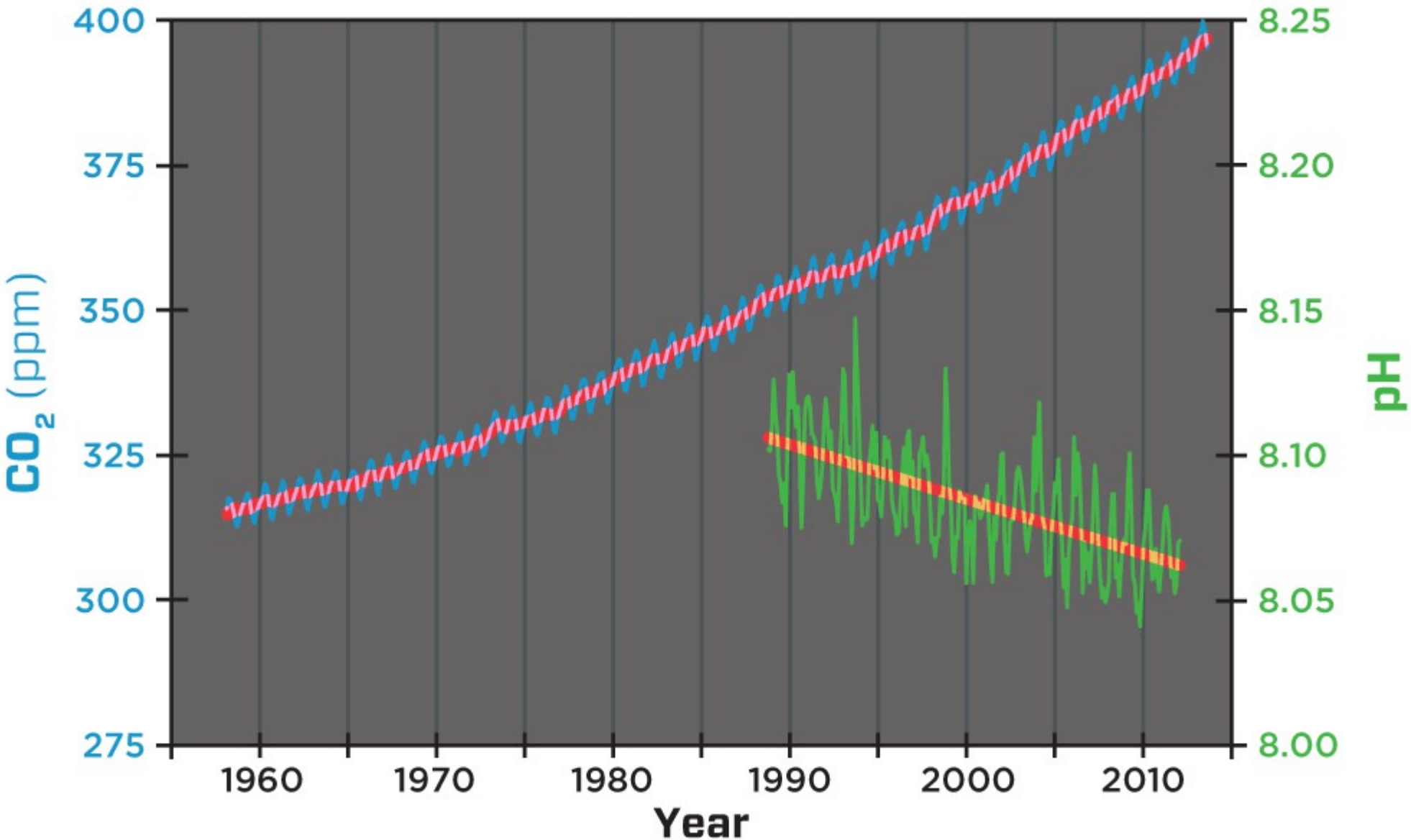
Ocean Sink

Ocean carbon sink continues to increase
2.6±0.5 GtC/yr for 2003–2012, 2.9±0.5 GtC/yr in 2012



Source: Le Quéré et al 2013; Global Carbon Project 2013 http://www.globalcarbonproject.org

Anthropogenic ocean acidification is currently on progress and it is measurable



http://www.igbp.net/download/18.30566fc6142425d6c91140a/1385975160621/OA_spm2-FULL-lorez.pdf

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a) CO_2 dissolves in seawater

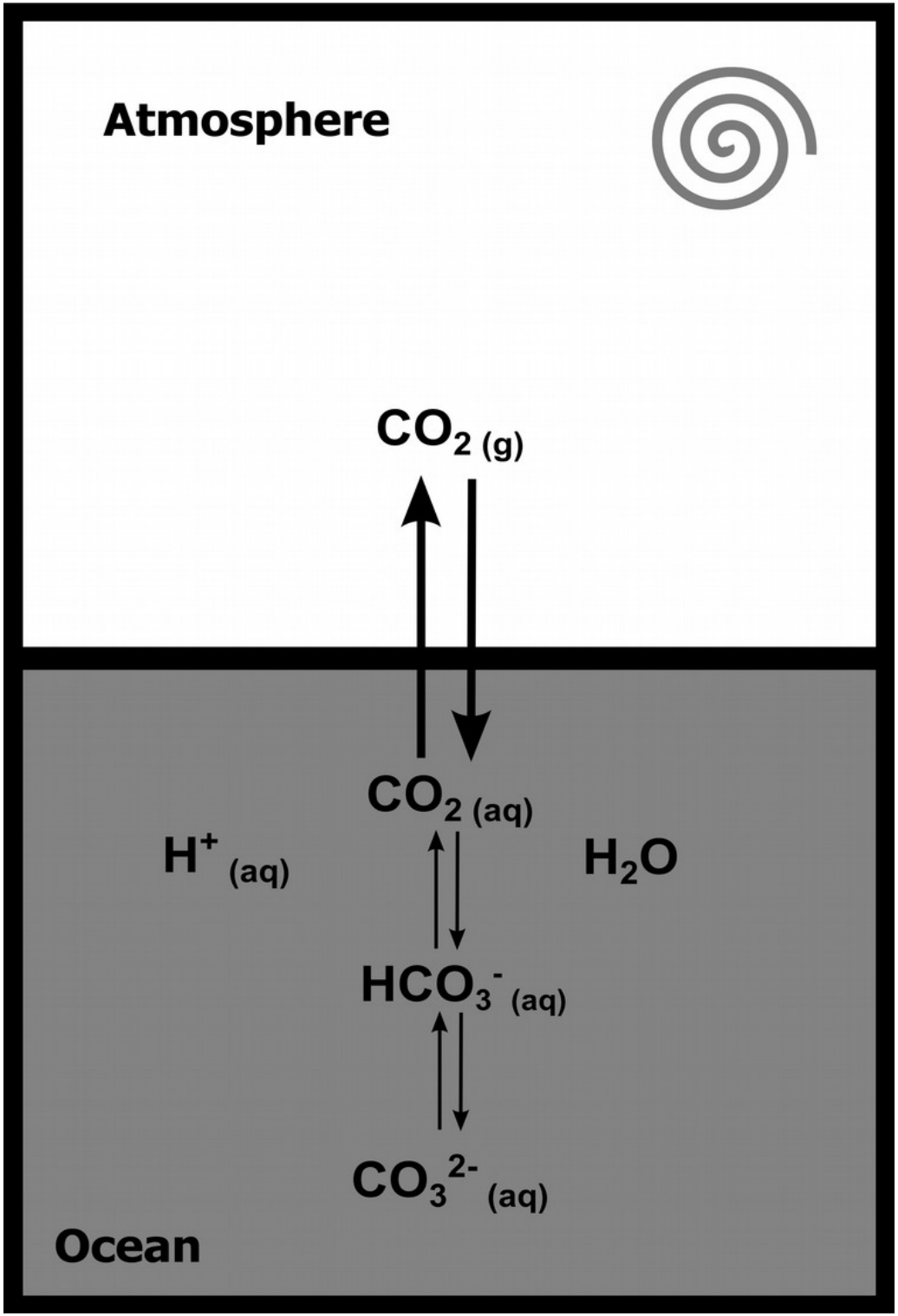
b) CO_2 reacts with water forming bicarbonate (HCO_3^-) and hydrogen (H^+) ions

c) These H^+ ions react with carbonate (CO_3^{-2}) ions, forming more HCO_3^-

d) Summarizing:

$$CO_{2(aq)} + CO_3^{-2} + H_2O \leftrightarrow 2HCO_3^-$$

e) [CO_2] and [HCO_3^-] increase, pH and [CO_3^{-2}] decrease



http://www.epoca-project.eu/index.php/guide-to-best-practices-for-ocean-acidification-research-and-data-reporting.html

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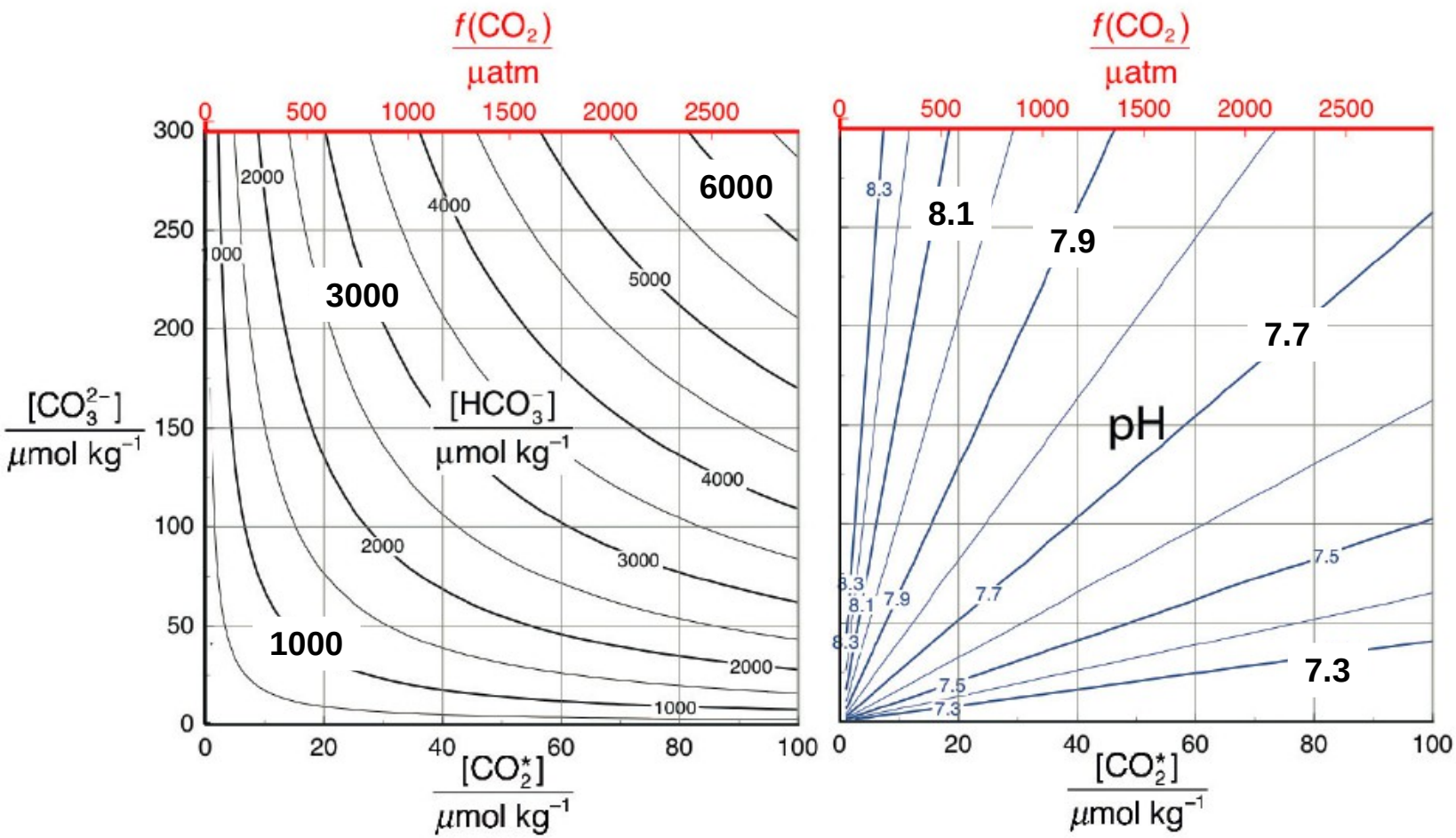
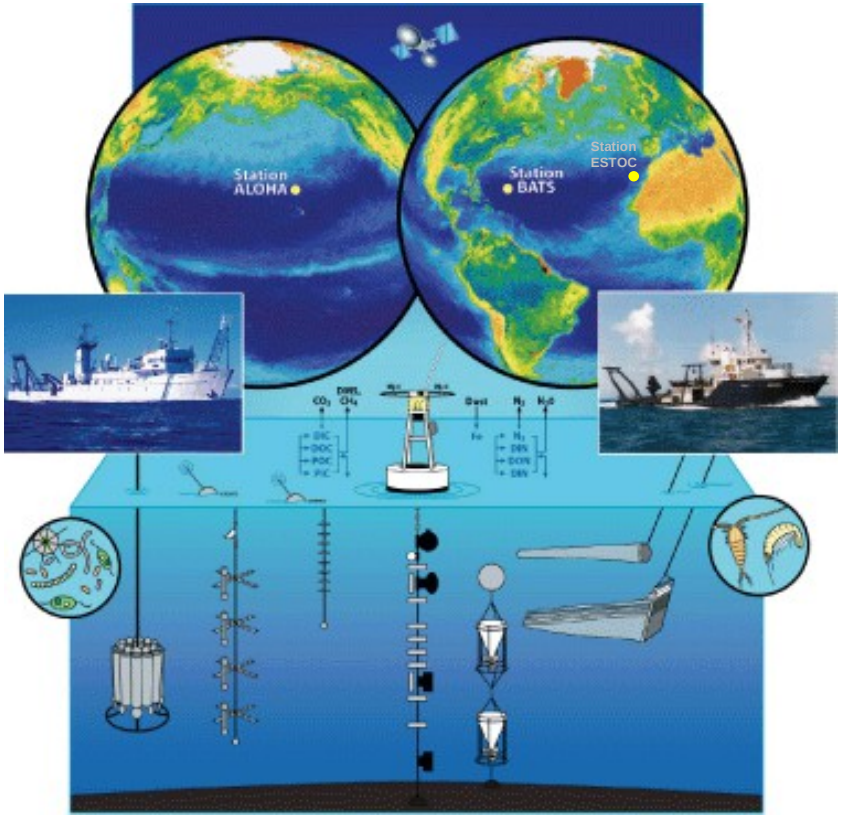
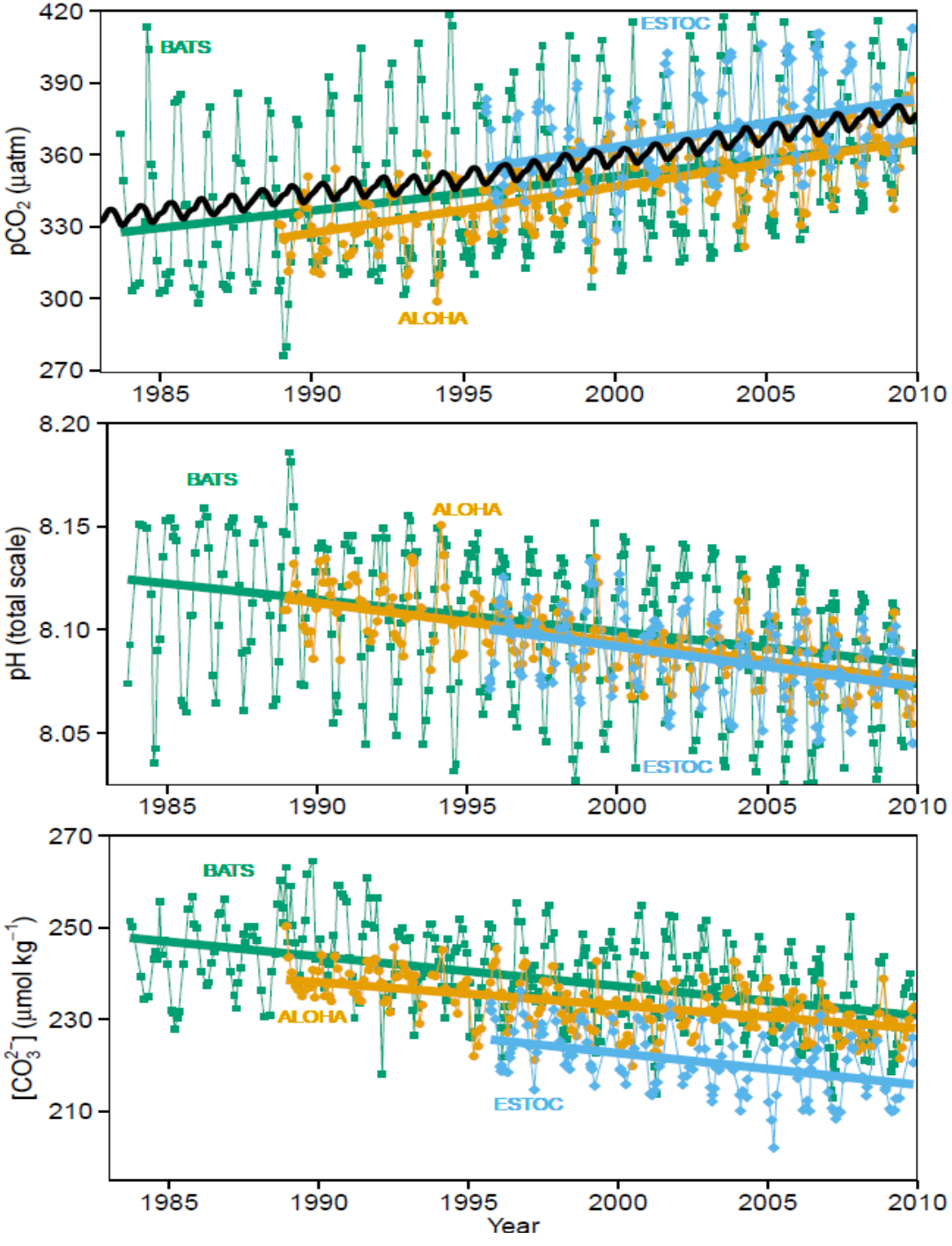


Figure 1.4a Plot of contours of constant bicarbonate concentration (µmol kg^{-1}) as a function of $[CO_2^*]$ and $[CO_3^{2-}]$. **1.4b**. Plot of contours of constant pH as a function of $[CO_2^*]$ and $[CO_3^{2-}]$.

http://www.epoca-project.eu/index.php/guide-to-best-practices-for-ocean-acidification-research-and-data-reporting.html

Change in pH from ocean acidification is already measurable





Data:
Bates (2007)
Dore et al. (2009)
Santana-Casiano et al. (2007)
Gonzàles-Dàvila et al. (2010)

IPCC AR5 WG1 Report, Chap. 3 (2013)

OCEAN ACIDIFICATION IN NUMBERS

40% The increase in atmospheric carbon dioxide (CO_2) levels since the start of the industrial revolution.

26% The increase in ocean acidity from preindustrial levels to today.

about 170% The projected increase in ocean acidity by 2100 compared with preindustrial levels if high CO_2 emissions continue (RCP* 8.5).

10 times The current rate of acidification is over 10 times faster than any time in the last 55 million years.

24 million The number of tonnes of CO_2 the ocean absorbs every day.

www.oceanacidification.net

Less available CO_3^{-2} in seawater means that:

- **Organisms building $CaCO_3$ structures (e.g. shells) will be affected**

$$CaCO_{3(s)} \leftrightarrow Ca^{+2}_{(aq)} + CO_3^{-2}{}_{(aq)}$$

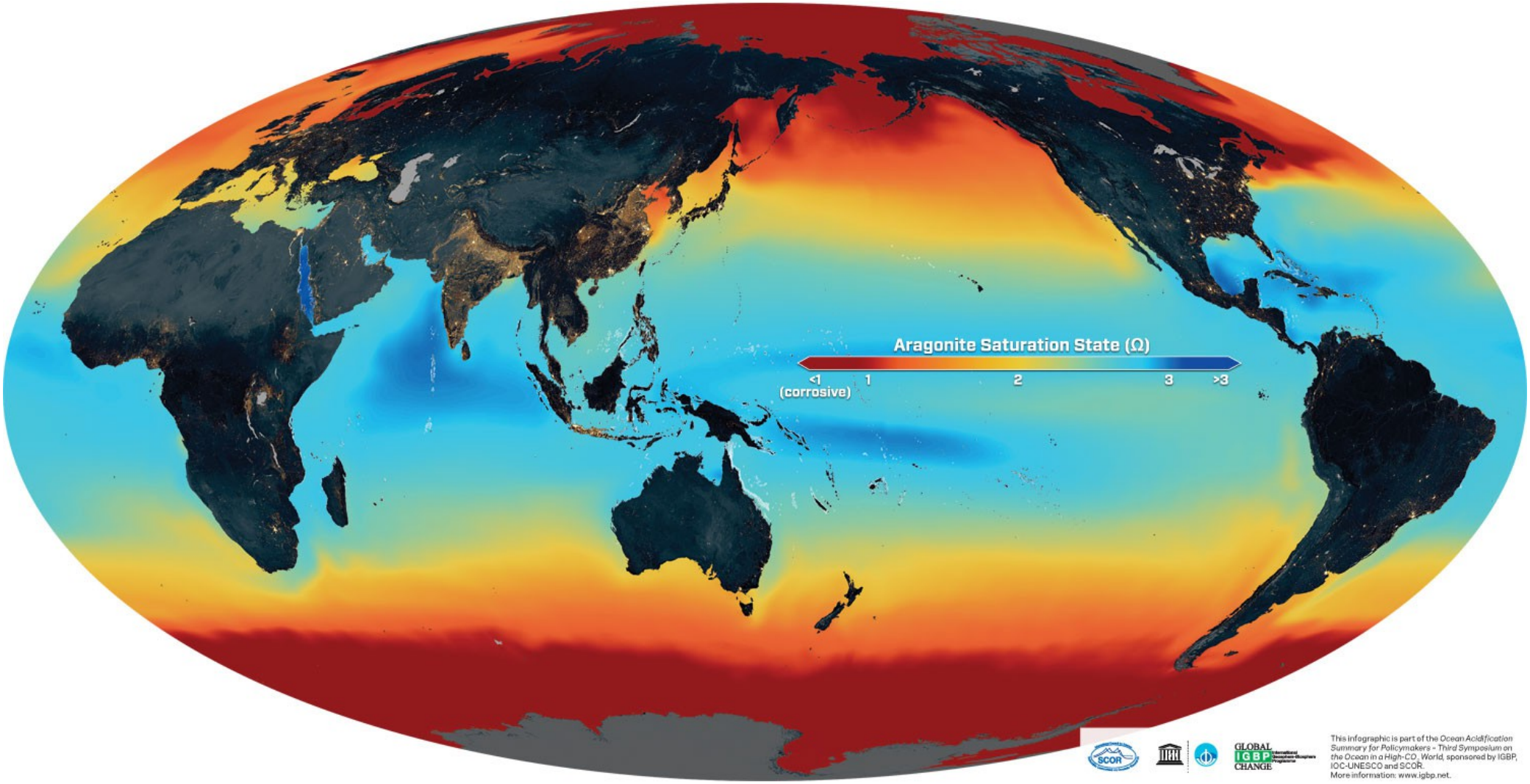
- **Equilibrium constant for this reaction is:**

$K_{sp} = [Ca^{+2}]*[CO_3^{-2}]$, where K_{sp} is the solubility product

- **In Marine Chemistry, we represent the "saturation state" of $CaCO_3$ (Ω) like this:**

$$\Omega = \frac{[Ca^{+2}]*[CO_3^{-2}]}{K^{\circ}_{sp}}$$

If Ω is > 1, seawater conditions are favourable for organisms to form shells while
If Ω is <1, seawater conditions are "corrosive" for shells and skeletons



http://ocean-acidification.net

Aragonite saturation state in the oceans: predictions for year 2100.
If Ω is less than 1 (Ω<1), conditions are corrosive (undersaturated) for aragonite-based shells and skeletons.
Coral growth benefits from Ω≥3.

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Contents lists available at ScienceDirect

Estuarine, Coastal and Shelf Science

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

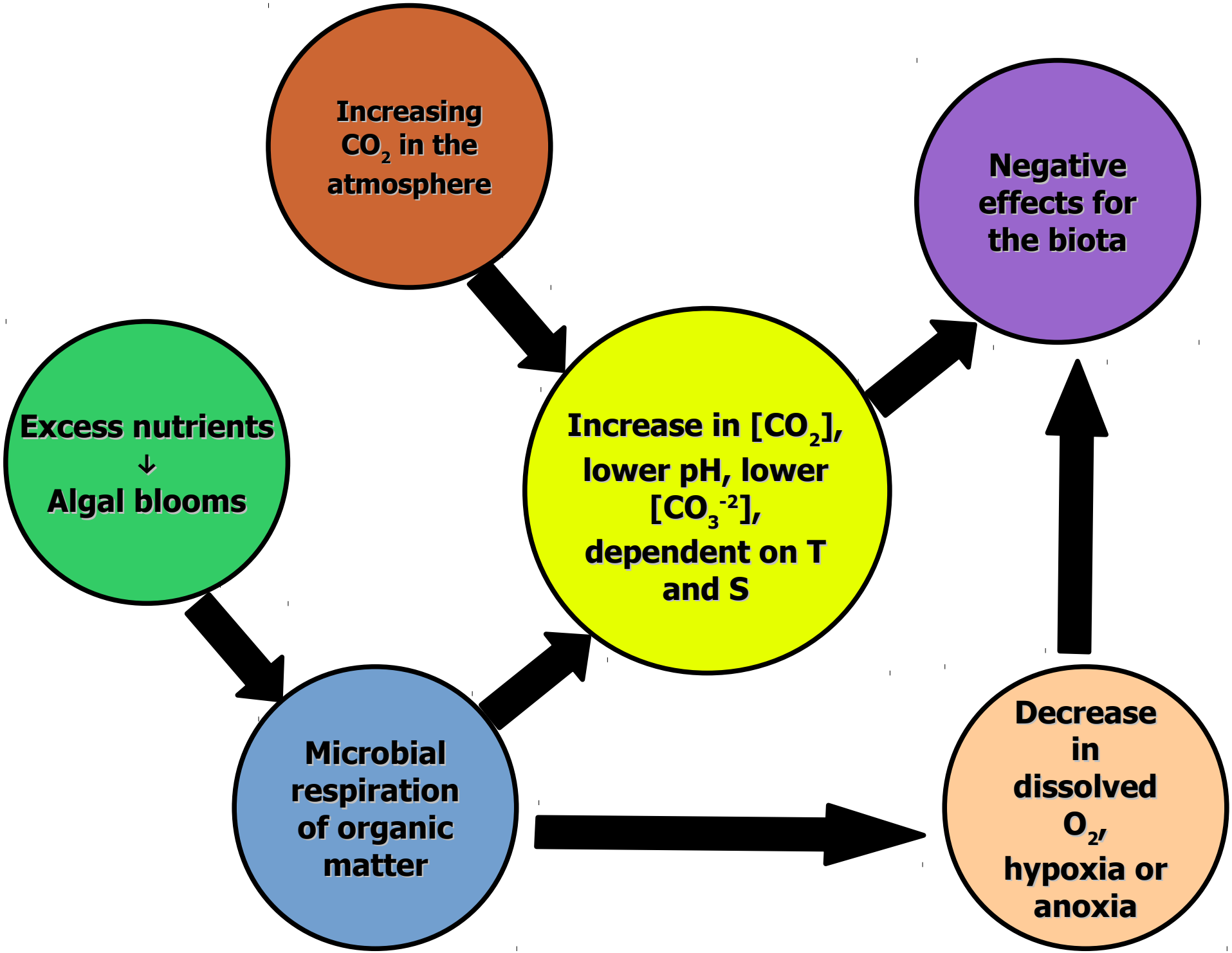
Invited feature

Coastal ocean acidification: The other eutrophication problem

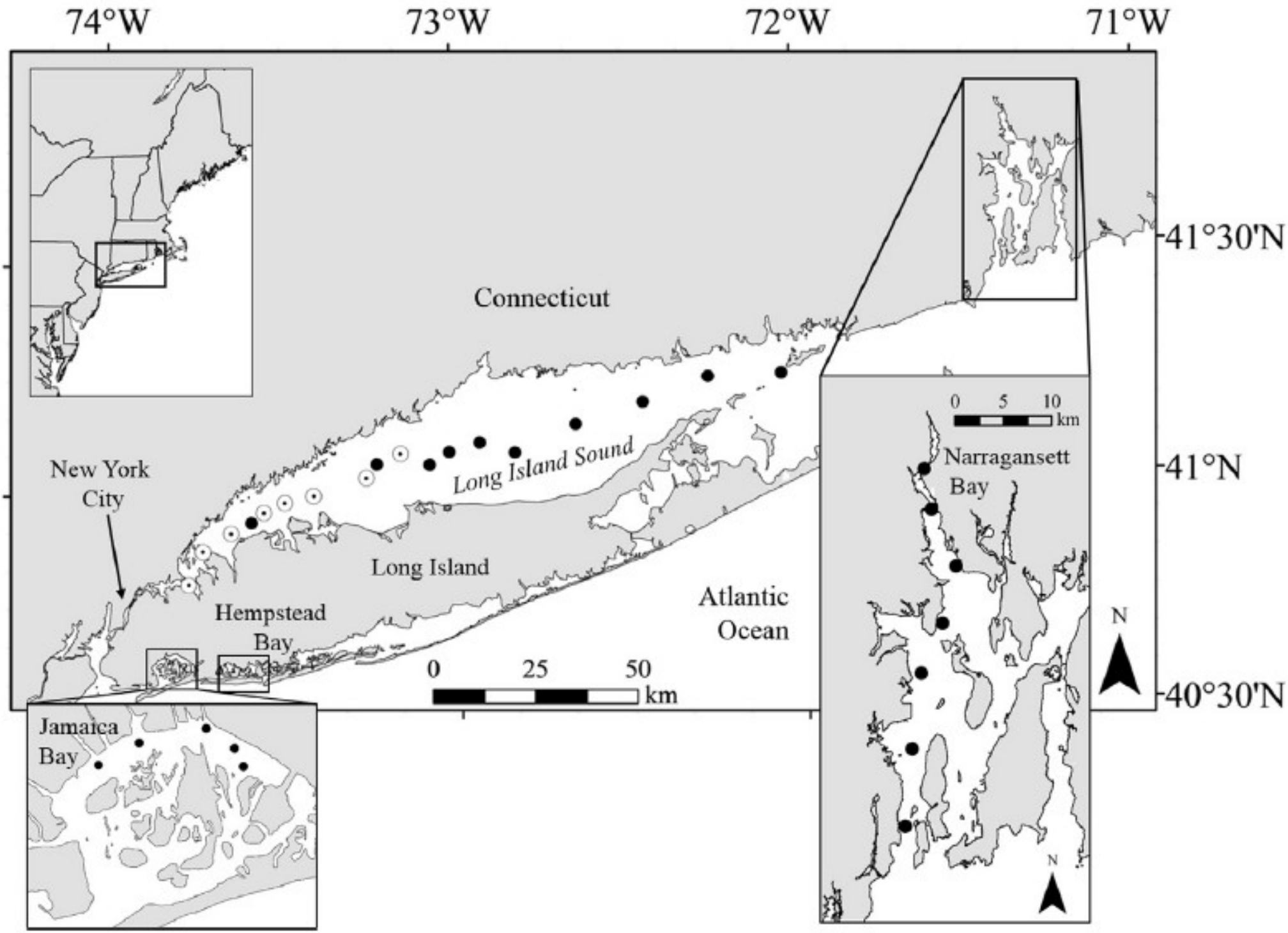
Ryan B. Wallace [a], Hannes Baumann [a], Jason S. Grear [b], Robert C. Aller [a], Christopher J. Gobler [a, *]

[a] Stony Brook University, School of Marine and Atmospheric Sciences, 239 Montauk Hwy, Southampton, NY 11968, USA
[b] US Environmental Protection Agency, Atlantic Ecology Division, National Health and Environmental Effects Research Laboratory, Office of Research and Development, 27 Tarzwell Dr, Narragansett, RI 02882, USA

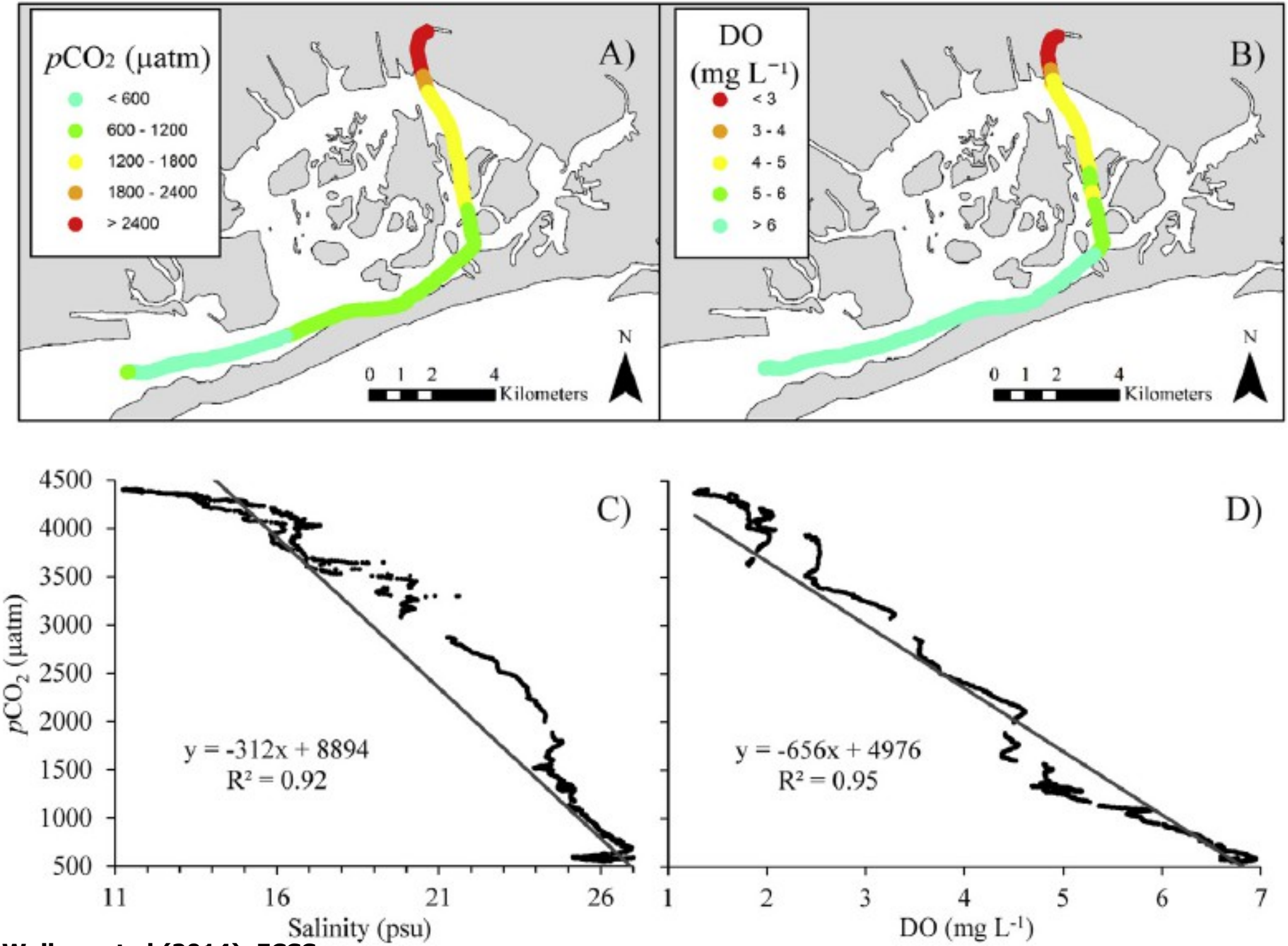
How does it exactly happen?



Sunda & Cai, dx.doi.org/10.1021/es300626f | Environ. Sci. Technol. 2012, 46, 10651−10659



Wallace et al (2014), ECSS.



Wallace et al (2014), ECSS.

Summarizing:

- **↑ anthropogenic nutrients → expansion of hypoxic/anoxic bottom waters;**
- **Combining low O_2 and high CO_2/low pH → negative effect on respiration → energy obtained from respiratory oxidation of organic matter is directly related to the log of the $[O_2]/[CO_2]$ ratio;**
- **Combining observations (LONG-TERM!) and model results: ↓ pH from respiration + ↑ atmospheric CO_2 will act in concert → combined pH effects will be more than additive;**
- **Negative impacts: coastal systems support most of world fisheries and aquaculture!**
- **Future impacts → dependent on T and S → influenced by climate change.**

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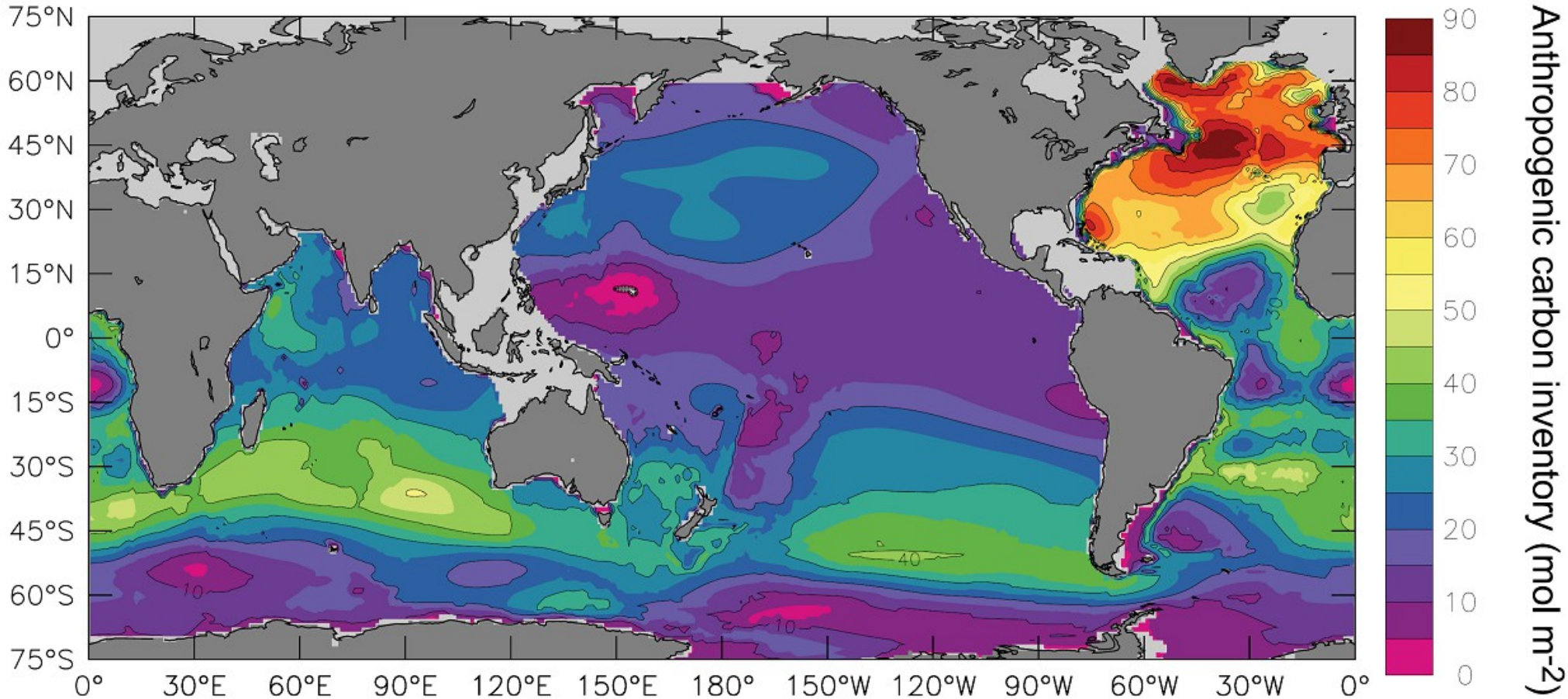


Figure 5.10. *Column inventory of anthropogenic carbon (mol m^{-2}) as of 1994 from Sabine et al. (2004b). Anthropogenic carbon is estimated indirectly by correcting the measured DIC for the contributions of organic matter decomposition and dissolution of carbonate minerals, and taking into account the DIC concentration the water had in the pre-industrial ocean when it was last in contact with the atmosphere. The global inventory of anthropogenic carbon taken up by the ocean between 1750 and 1994 is estimated to be 118 ± 19 GtC.*

IPCC 4th Assessment Report – WG1 – 2007 & Sabine et al (2004), Science

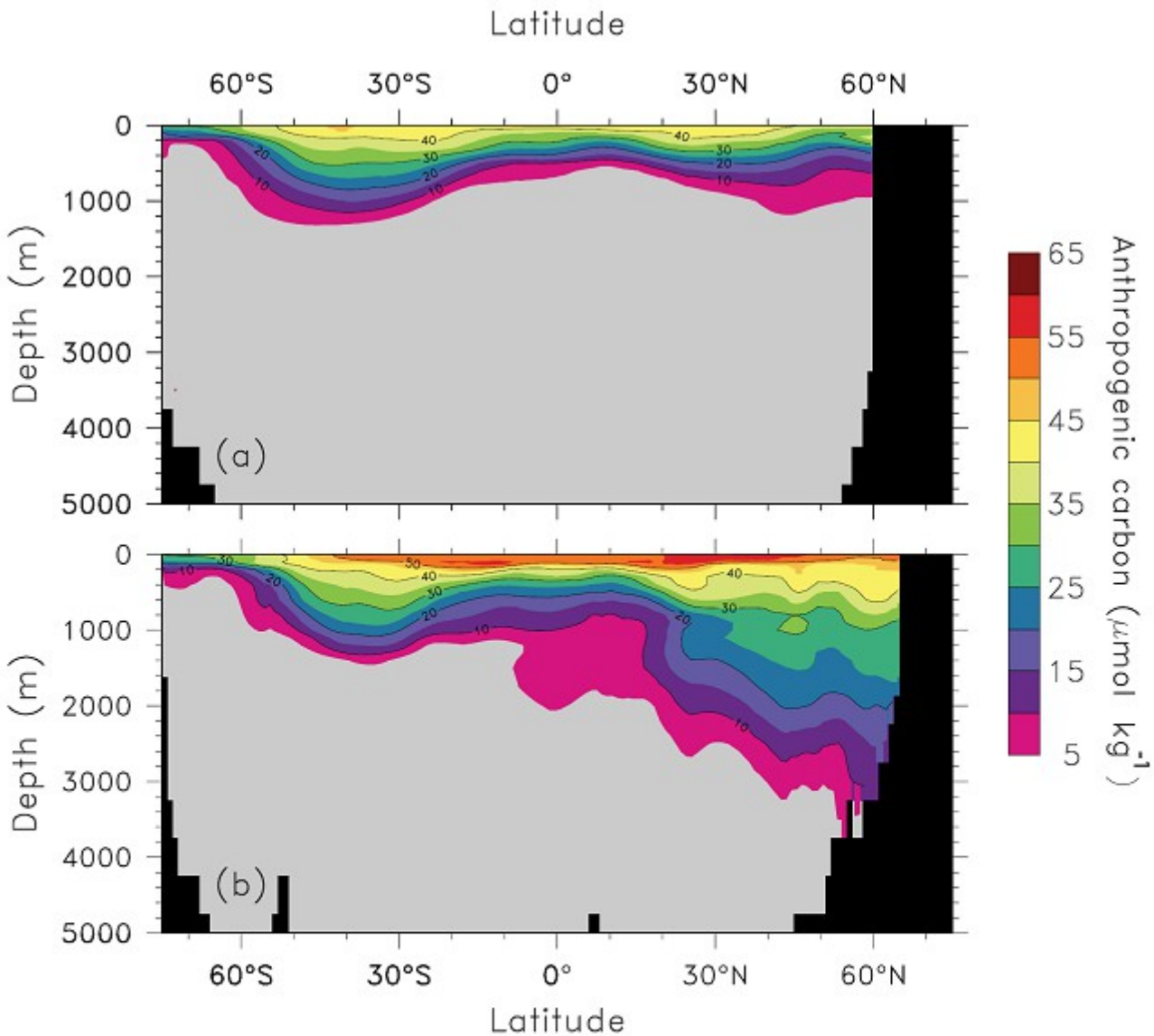


Figure 5.11. *Mean concentration of anthropogenic carbon as of 1994 in μmol kg⁻¹ from Sabine et al. (2004b) averaged over (a) the Pacific and Indian Oceans and (b) the Atlantic Ocean. The calculation of anthropogenic carbon is described in the caption of Figure 5.10 and in the text (Section 5.4).*

IPCC 4th Assessment Report – WG1 – 2007 & Sabine et al (2004), Science

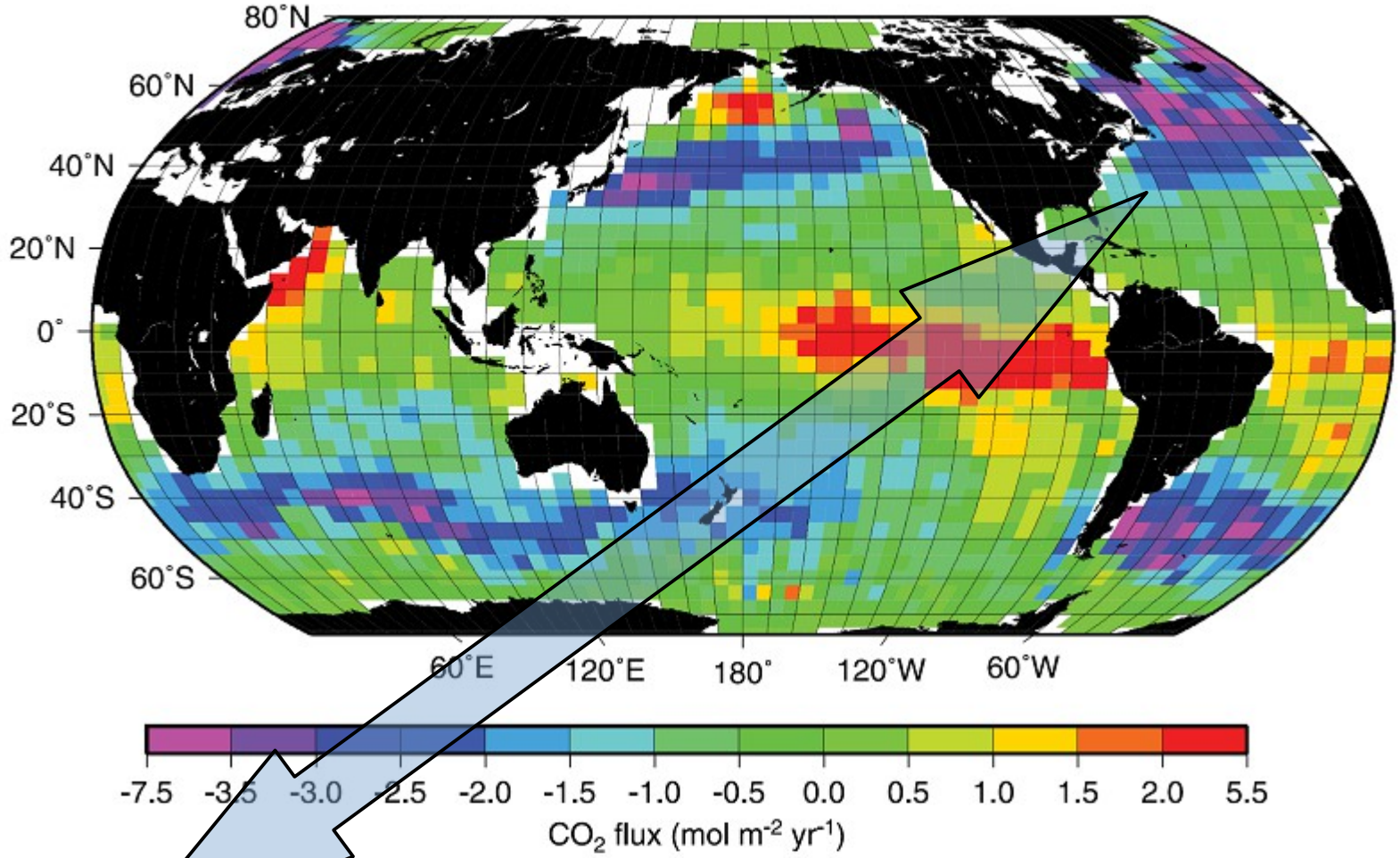
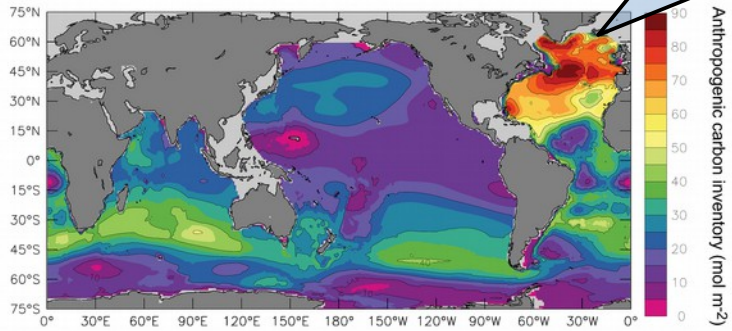


Figure 7.8. *Estimates (4° × 5°) of sea-to-air flux of CO_2, computed using 940,000 measurements of CO_2 collected since 1956 and averaged monthly, together with NCEP/NCAR 41-year wind speeds and a (10-m wind speed)^2 dependence on the gas transfer rate (Wanninkhof, were normalised to the year 1995 using techniques described in Takahashi et al. (2002), speeds taken at the 0.995 standard deviation level (about 40 m above the sea surface). CO_2 for 1995 with 10-m winds is –1.6 GtC yr^{-1}, with an approximate uncertainty of ±1 GtC yr^{-1}, mainly due to uncertainty in the gas exchange velocity and limited data timated global flux consists of an uptake of anthropogenic CO_2 of –2.2 GtC yr^{-1} (see text) g of 0.6 GtC yr^{-1}, corresponding primarily to oxidation of organic carbon borne by rivers (Figure 7.5). The monthly flux values with 10-m winds used here are available from T. Takahashi at http://www.ldeo.columbia.edu/res/pi/CO2/carbondioxide/pages/air_sea_flux_rev1.html.*



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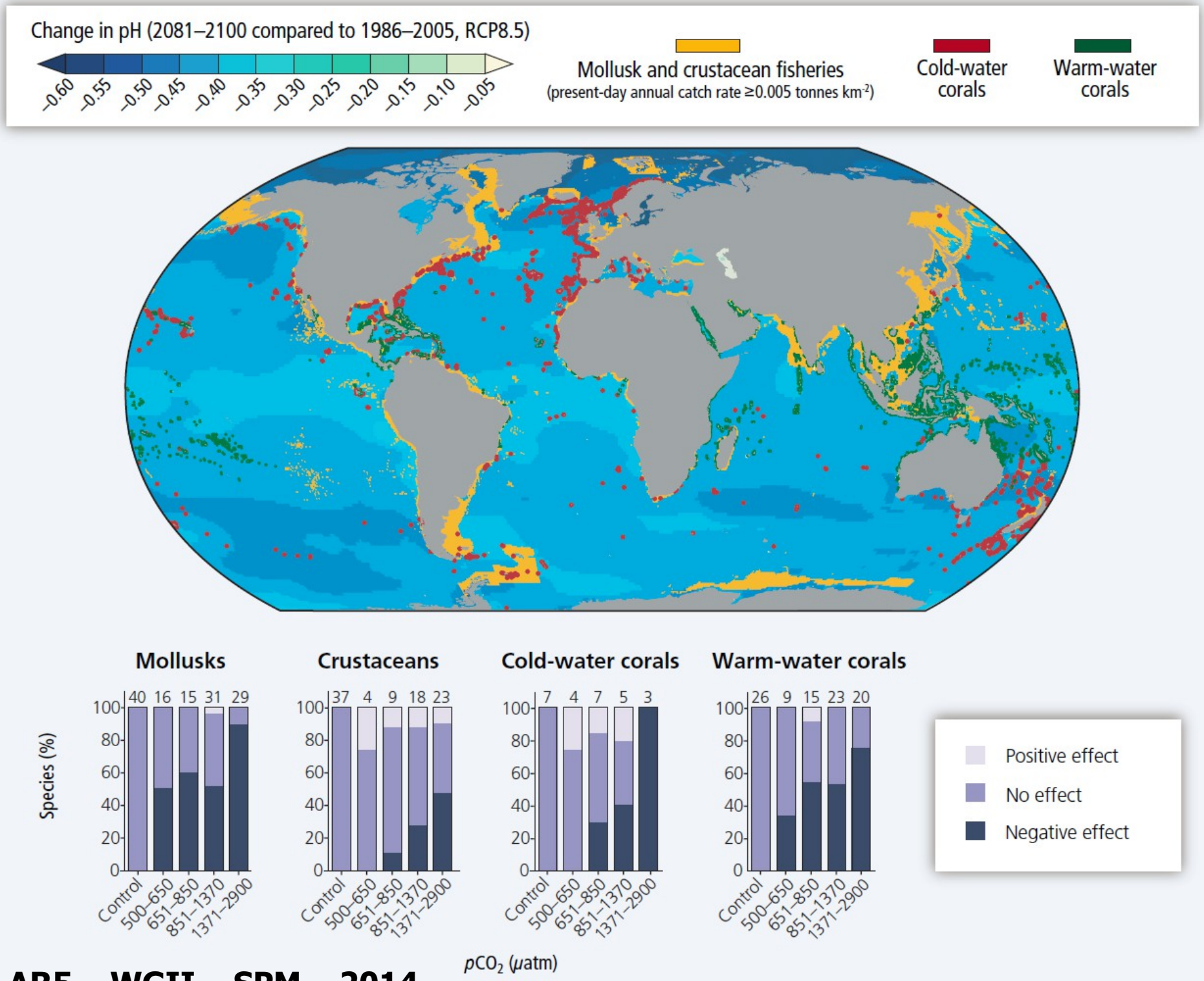
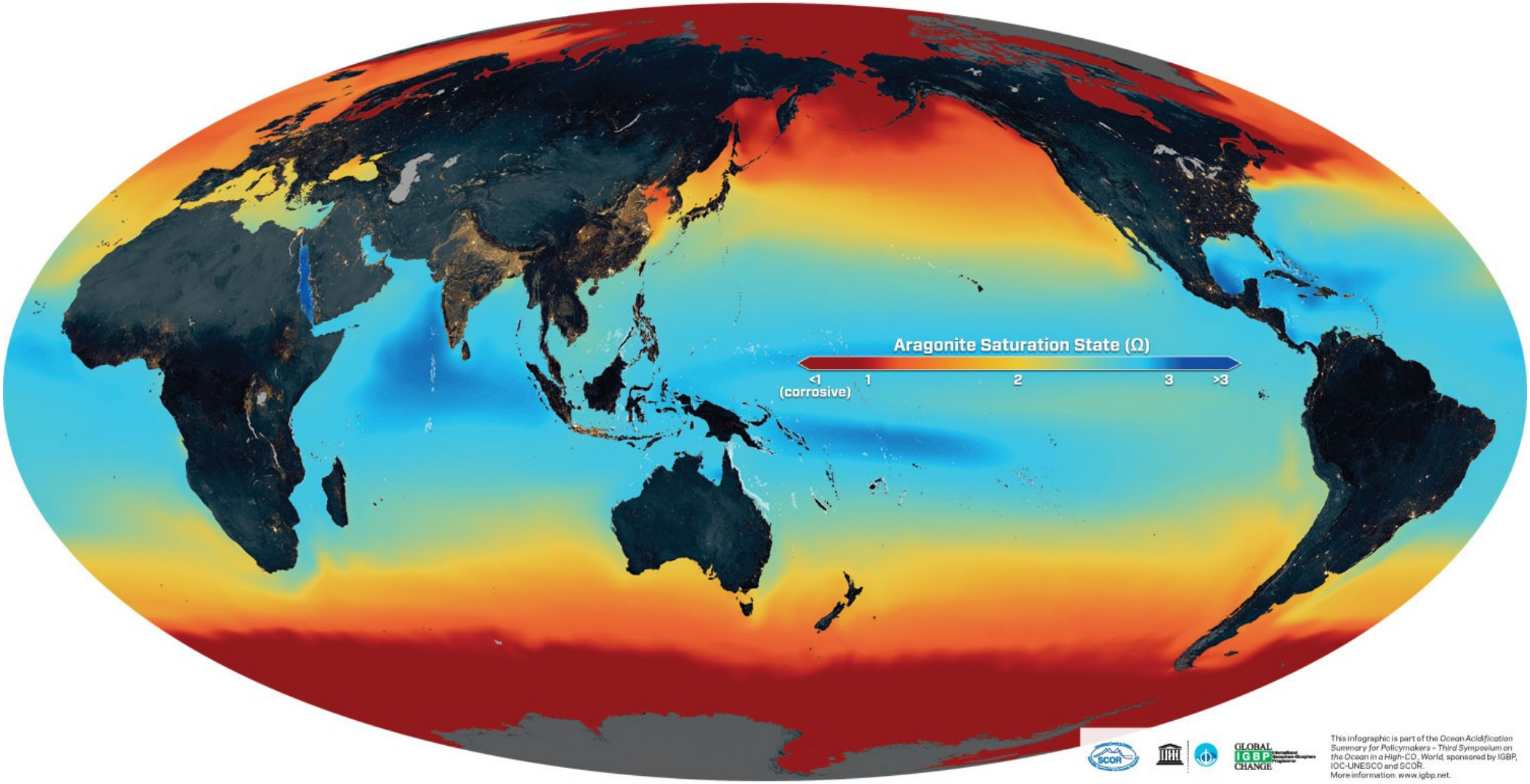
(B)



IPCC AR5 – WGII – SPM – 2014



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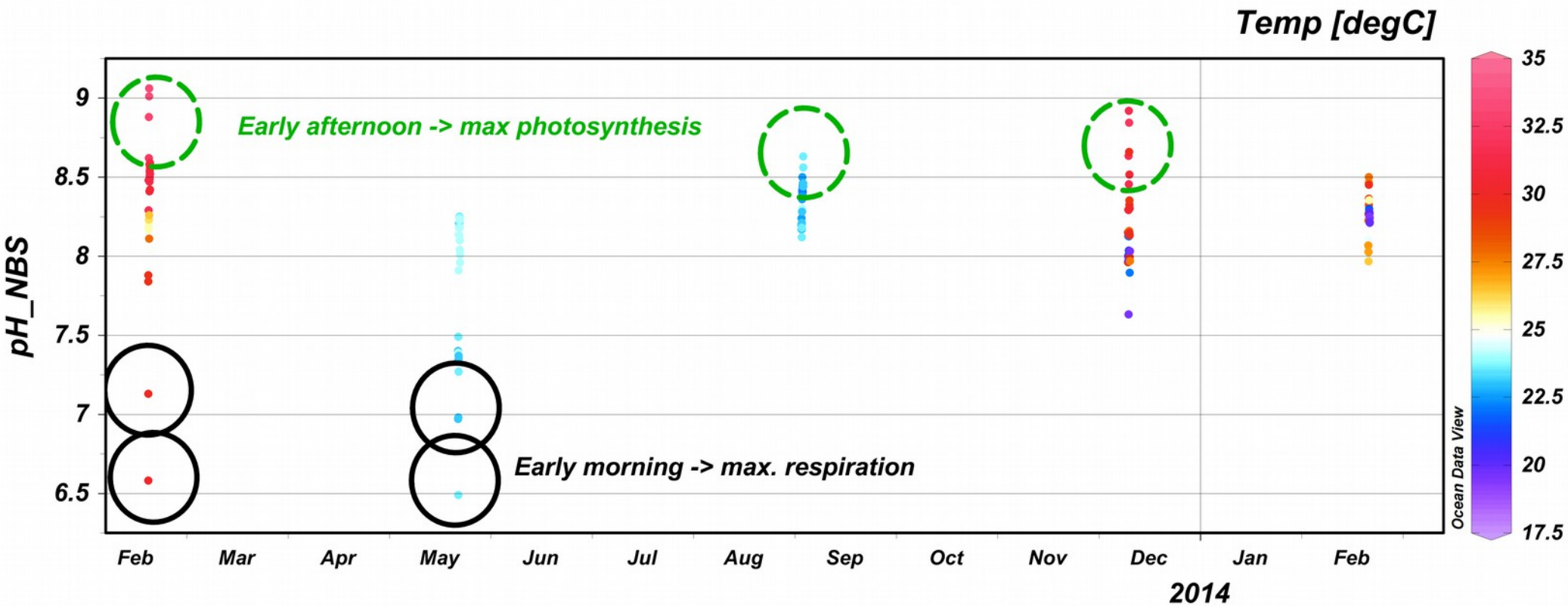
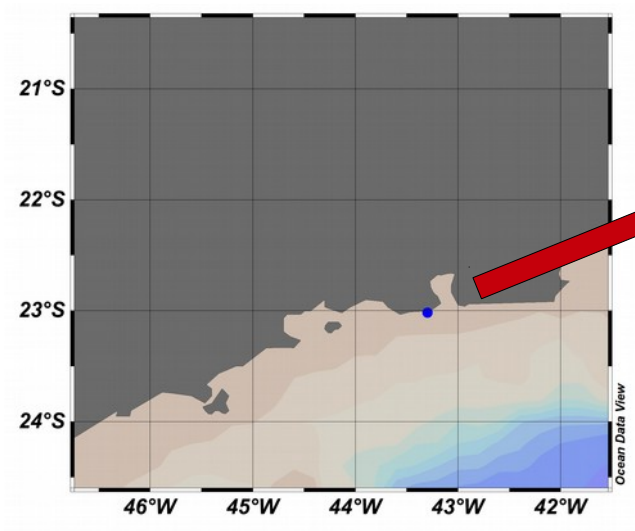
Continental margins and coastal ecosystems

- Extreme heterogeneity
- CO_2 system regulated by nutrients + biological processes in these areas
- CO_2 system parameters vary at daily AND seasonal time scales
- Lack of long term observations + inadequacy of global biogeochemistry models resolving these areas
- How would anthropogenic CO_2 influence these areas?



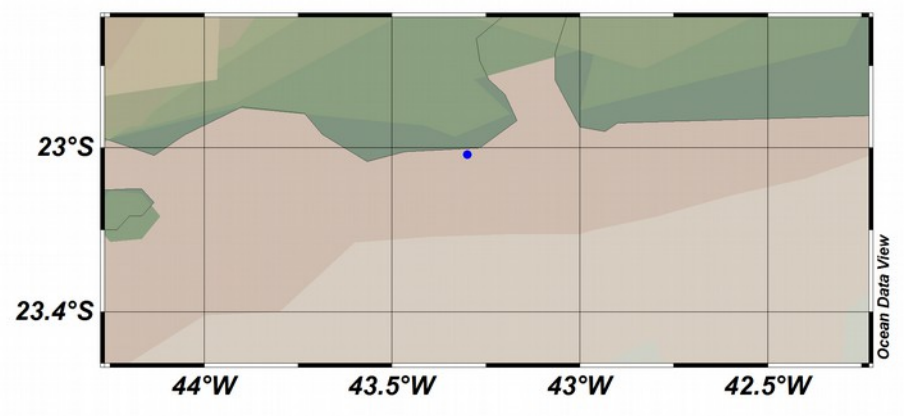


Joatinga Channel → Eutrophic , urban area (Rio de Janeiro)

(Soares, Farias, Hamacher, Araújo & Da Cunha, unpublished data)

Flood tide – Dec 2013

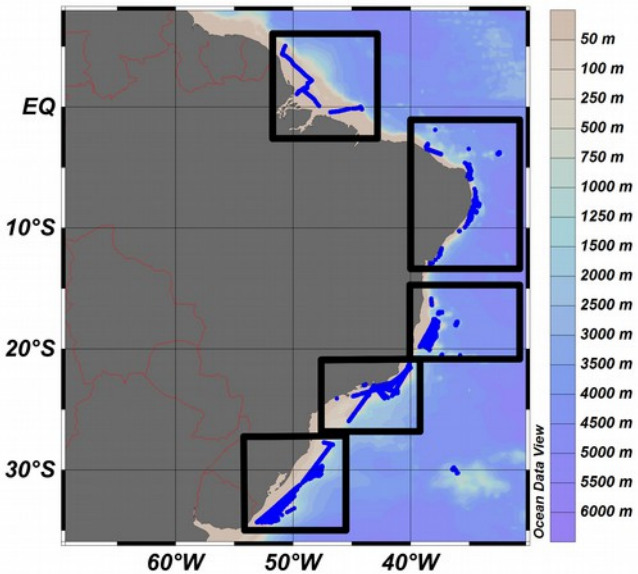
Low tide – Dec 2013

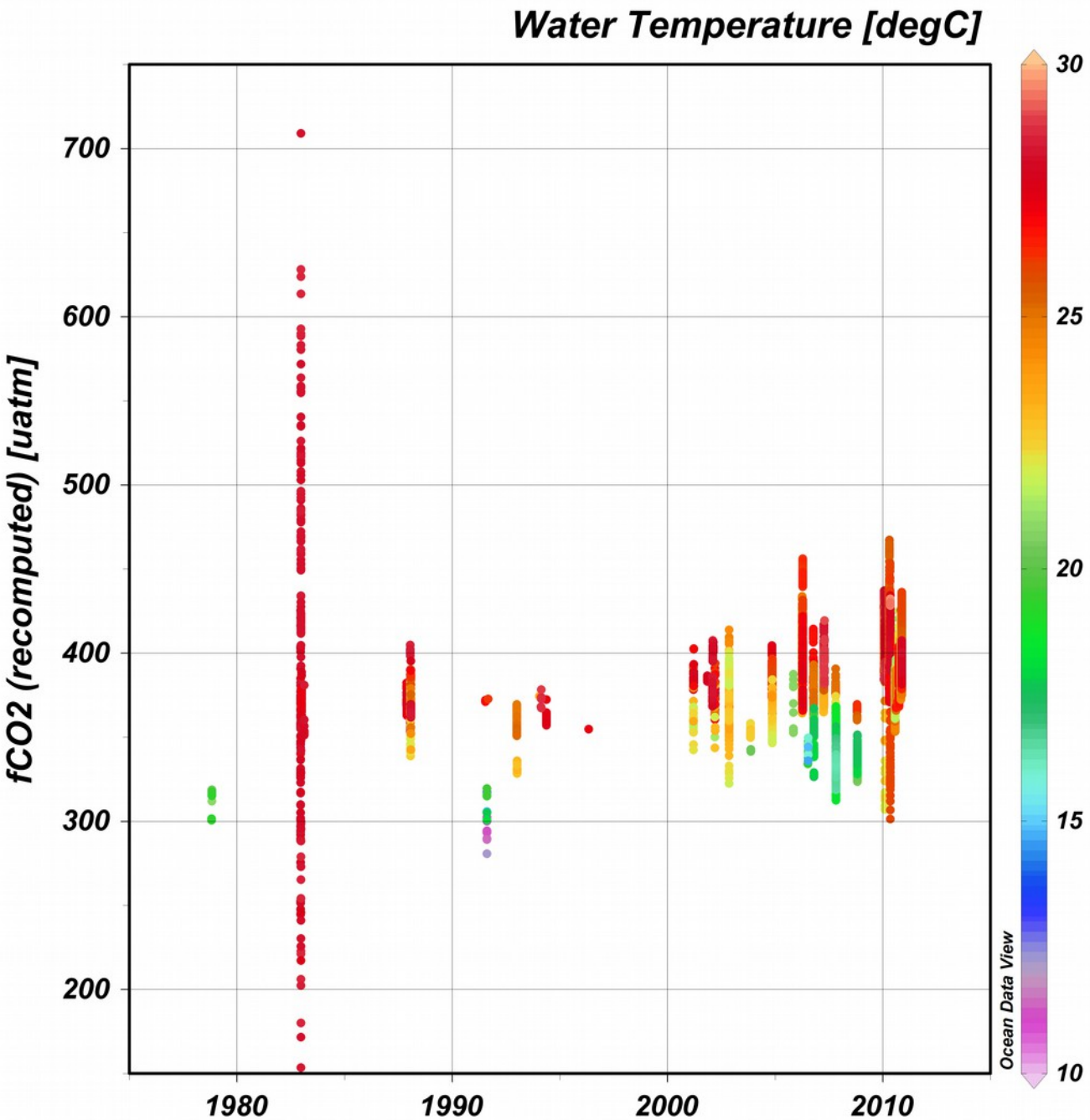


Brazilian continental shelf

SOCAT v.2 data

Bakker et al (2013)
d.o.i. 10.5194/essdd-6-465-2013



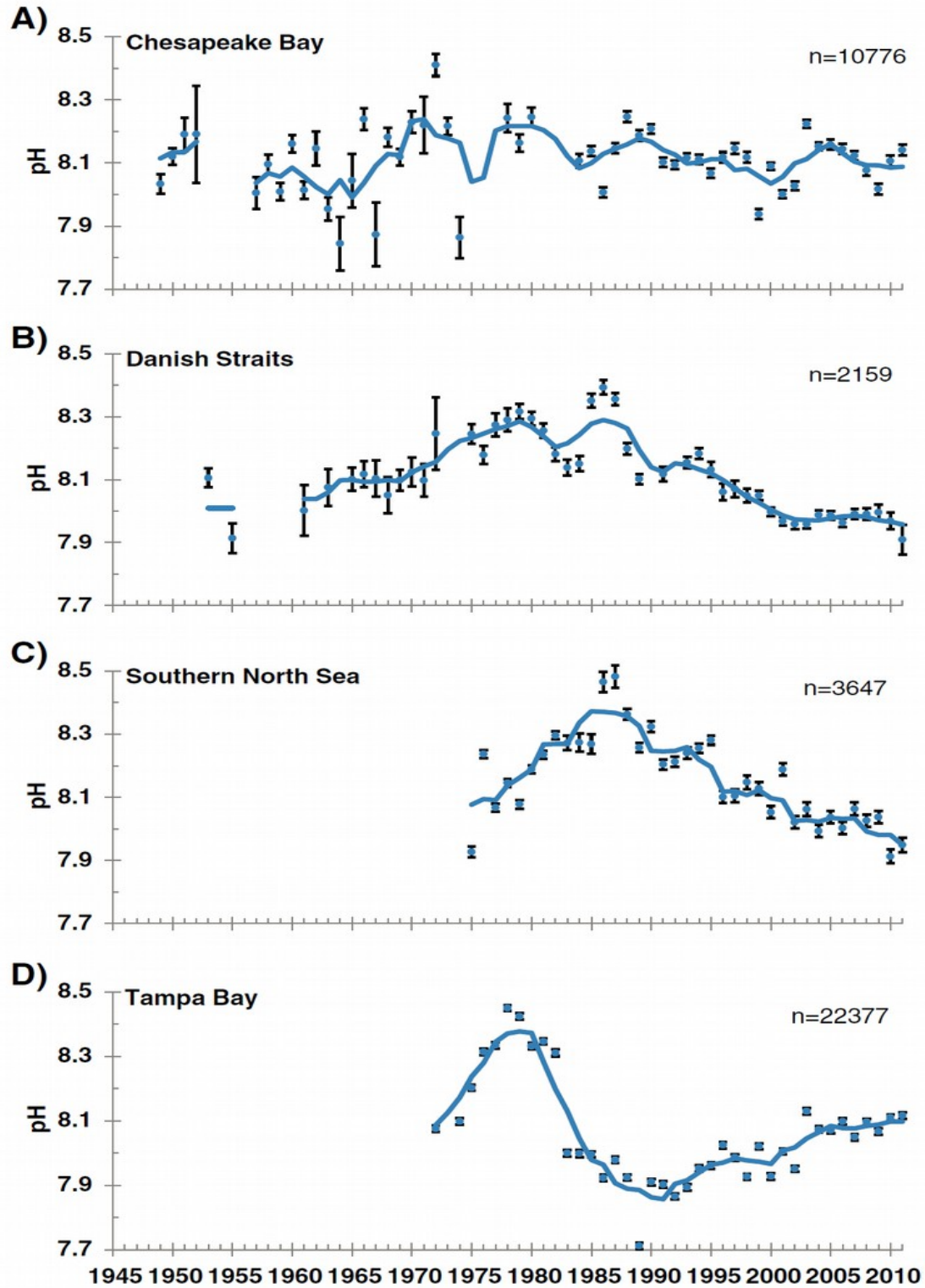


Da Cunha & Moser, in preparation

Long-term data for some N-hemisphere coastal areas

(from Duarte et al 2013 doi 10.1007/s12237-013-9594-3)

Do you see any trends in these graphics???



Canal da Joatinga, Rio de Janeiro, Dec. 2013

- **Start long-term observations**
- **Adopt a "typology" for coastal areas/ecosystems**
- **Downscale marine biogeochemistry models to resolve these areas**
- **Effective coastal ecosystem management for conservation and mitigation**

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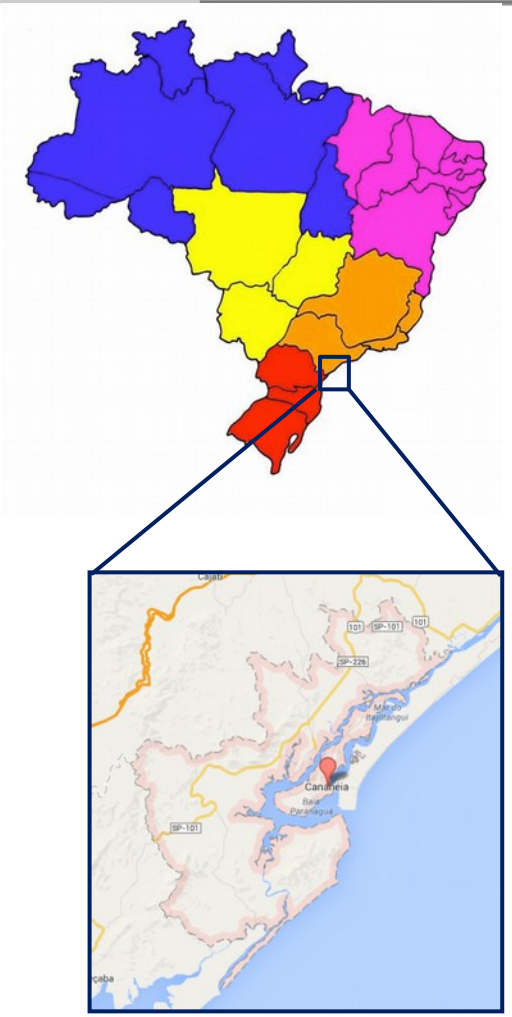
Group formation



GLOBAL CHANGE IGBP International Geosphere-Biosphere Programme Brazil Regional Office

INPE

USP Universidade de São Paulo

CNPq Conselho Nacional de Desenvolvimento Científico e Tecnológico

Brazil and the ocean acidification issue

Mission + objectives

Establish a national research network focused on all issues regarding OA, including capacity building

Objectives:

❖ *short-term:*

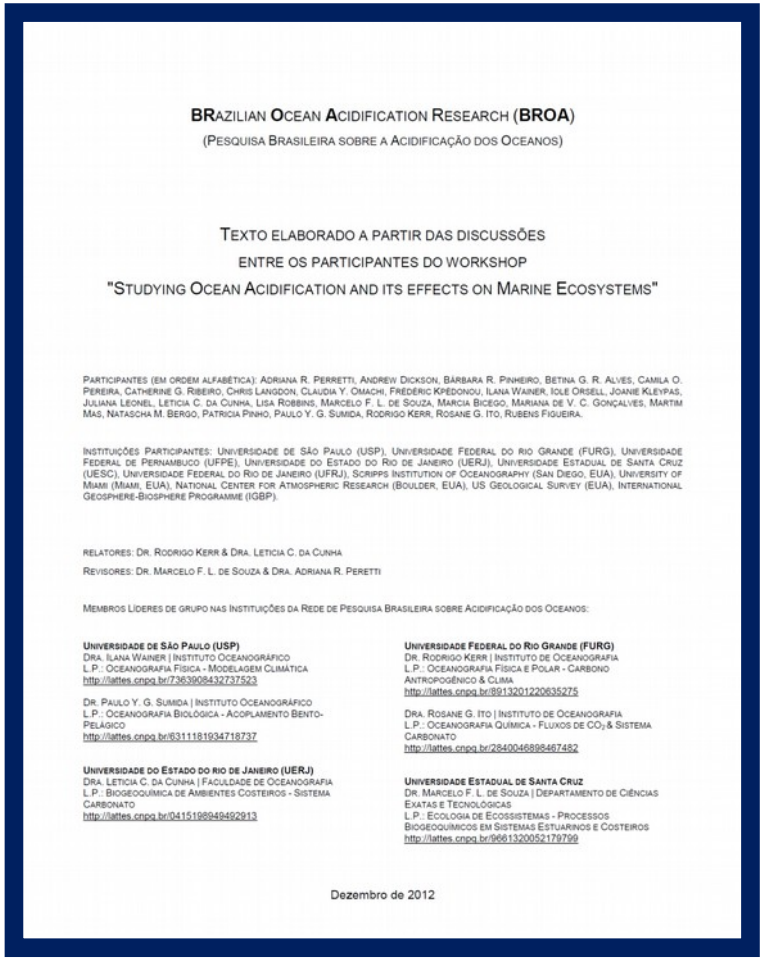
Identify and integrate BR research groups dealing with OA issues, and contribute to international ongoing programmes.

❖ *medium-term:*

Integrate analytical facilities for OA research in the country; adopt a national protocol for chemical analyses and biological essays; certify results against reference materials and intercalibration exercises

❖ *long-term:*

Capacity building: critical mass of trained researchers and technicians able to deal with OA issues → improve scientific knowledge; identify and protect ecosystems at risk; manage fisheries, aquaculture, tourism.



BRAZILIAN OCEAN ACIDIFICATION RESEARCH (BROA)

(PESQUISA BRASILEIRA SOBRE A ACIDIFICAÇÃO DOS OCEANOS)

TEXTO ELABORADO A PARTIR DAS DISCUSSÕES
ENTRE OS PARTICIPANTES DO WORKSHOP
"STUDYING OCEAN ACIDIFICATION AND ITS EFFECTS ON MARINE ECOSYSTEMS"

PARTICIPANTES (EM ORDEM ALFABÉTICA): ADRIANA R. PERRETTI, ANDREW DICKSON, BÁRBARA R. PINHEIRO, BETINA G. R. ALVES, CAMILA O. PEREIRA, CATHERINE G. RIBEIRO, CHRIS LANGDON, CLAUDIA Y. OMACHI, FRÉDERIC KPÉDONOU, ILANA WAINER, IOLE ORSELL, JOANIE KLEYPAS, JULIANA LEONEL, LETICIA C. DA CUNHA, LISA ROBBINS, MARCELO F. L. DE SOUZA, MARCIA BICEGO, MARIANA DE V. C. GONÇALVES, MARTIM MAS, NATASCHA M. BERGO, PATRICIA PINHO, PAULO Y. G. SUMIDA, RODRIGO KERR, ROSANE G. ITO, RUBENS FIGUEIRA.

INSTITUIÇÕES PARTICIPANTES: UNIVERSIDADE DE SÃO PAULO (USP), UNIVERSIDADE FEDERAL DO RIO GRANDE (FURG), UNIVERSIDADE FEDERAL DE PERNAMBUCO (UFPE), UNIVERSIDADE DO ESTADO DO RIO DE JANEIRO (UERJ), UNIVERSIDADE ESTADUAL DE SANTA CRUZ (UESC), UNIVERSIDADE FEDERAL DO RIO DE JANEIRO (UFRJ), SCRIPPS INSTITUTION OF OCEANOGRAPHY (SAN DIEGO, EUA), UNIVERSITY OF MIAMI (MIAMI, EUA), NATIONAL CENTER FOR ATMOSPHERIC RESEARCH (BOULDER, EUA), US GEOLOGICAL SURVEY (EUA), INTERNATIONAL GEOSPHERE-BIOSPHERE PROGRAMME (IGBP).

RELATORES: DR. RODRIGO KERR & DRA. LETICIA C. DA CUNHA

REVISORES: DR. MARCELO F. L. DE SOUZA & DRA. ADRIANA R. PERETTI

MEMBROS LÍDERES DE GRUPO NAS INSTITUIÇÕES DA REDE DE PESQUISA BRASILEIRA SOBRE ACIDIFICAÇÃO DOS OCEANOS:

UNIVERSIDADE DE SÃO PAULO (USP)
DRA. ILANA WAINER | INSTITUTO OCEANOGRÁFICO
L.P.: OCEANOGRAFIA FÍSICA - MODELAGEM CLIMÁTICA
http://lattes.cnpq.br/7363908432737523

DR. PAULO Y. G. SUMIDA | INSTITUTO OCEANOGRÁFICO
L.P.: OCEANOGRAFIA BIOLÓGICA - ACOPLAMENTO BENTO-PELÁGICO
http://lattes.cnpq.br/6311181934718737

UNIVERSIDADE DO ESTADO DO RIO DE JANEIRO (UERJ)
DRA. LETICIA C. DA CUNHA | FACULDADE DE OCEANOGRAFIA
L.P.: BIOGEOQUÍMICA DE AMBIENTES COSTEIROS - SISTEMA CARBONATO
http://lattes.cnpq.br/0415198949492913

UNIVERSIDADE FEDERAL DO RIO GRANDE (FURG)
DR. RODRIGO KERR | INSTITUTO DE OCEANOGRAFIA
L.P.: OCEANOGRAFIA FÍSICA E POLAR - CARBONO ANTROPOGÊNICO & CLIMA
http://lattes.cnpq.br/8913201220635275

DRA. ROSANE G. ITO | INSTITUTO DE OCEANOGRAFIA
L.P.: OCEANOGRAFIA QUÍMICA - FLUXOS DE CO_2 & SISTEMA CARBONATO
http://lattes.cnpq.br/2840046898467482

UNIVERSIDADE ESTADUAL DE SANTA CRUZ
DR. MARCELO F. L. DE SOUZA | DEPARTAMENTO DE CIÊNCIAS EXATAS E TECNOLÓGICAS
L.P.: ECOLOGIA DE ECOSSISTEMAS - PROCESSOS BIOGEOQUÍMICOS EM SISTEMAS ESTUARINOS E COSTEIROS
http://lattes.cnpq.br/9661320052179799

Dezembro de 2012

Downloadable @:

http://joomla.furg.br/broa/images/doc/BROA.pdf

BrOA today

Today we are:
8 institutions
33 Researchers
16 Students

DIRETÓRIO DOS GRUPOS DE PESQUISA NO BRASIL
Lattes

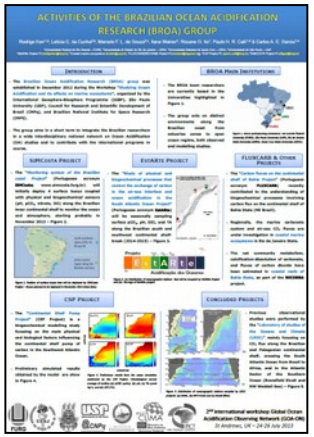
BrOA is registered within CNPq research groups

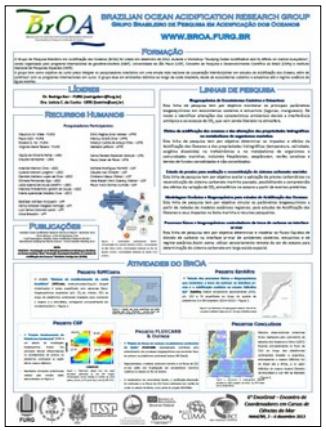
Research themes:

1) Coastal ocean and estuarine biogeochemistry.
2) Effects of OA and ecosystem chemistry in marine organisms
3) Use of proxies to evaluate marine carbonate system changes, paleaoceanography.
4) Ocean circulation and biogeochemistry modelling applied to OA issues.
5) Physical and biogeochemical processes controlling sea-air CO_2 fluxes.

2013 activities

- ✓ *1st BrOA report (Dec 2012)*
- ✓ *GOA-ON Workshop (Jul)*
- ✓ *BrOA webpage released (Sep)*
- ✓ *Brazil-France Meeting (Nov)*
- ✓ *6th EncoGrad meeting (Dec)*
- ✓ *Rede Clima workshop (Dec)*
- ✓ *Brazilian SOLAS representant Dr. Leticia da Cunha*
- ✓ *Scientific projects approved*





"Overview of the effects of increasing atmospheric CO_2 on the building organisms at Rocas Atoll- RN"

Bárbara Pinheiro- Rebecca Albright- Manuel Flores
barbara.pinheiro@gmail.com

CO_2 characterization: biogeochemical cycle at Rocas Atoll

Water sampling and analysis at Rocas Atoll pools

Temperature, condutivity (salinity), pH, dissolved oxigen, and total alcalinity

How ocean acidification and rising sea surface temperature will influence the development of coral recruits?

Experiment with *Siderastrea stellata* e *Porites astreoides* recruits

Scenarios according to the increase of CO_2 and sea surface temperature predicted on the IPCC

Acknowledgment: CNPq, Atol das Rocas

Sponsor: Fundação Grupo Boticário de Proteção à Natureza

What do we need at present in Brazil?

- **Long-term coastal monitoring programmes (define key parameters, automated AND integrated regional observatories)**
- **Capacity building (all levels, including technicians)**

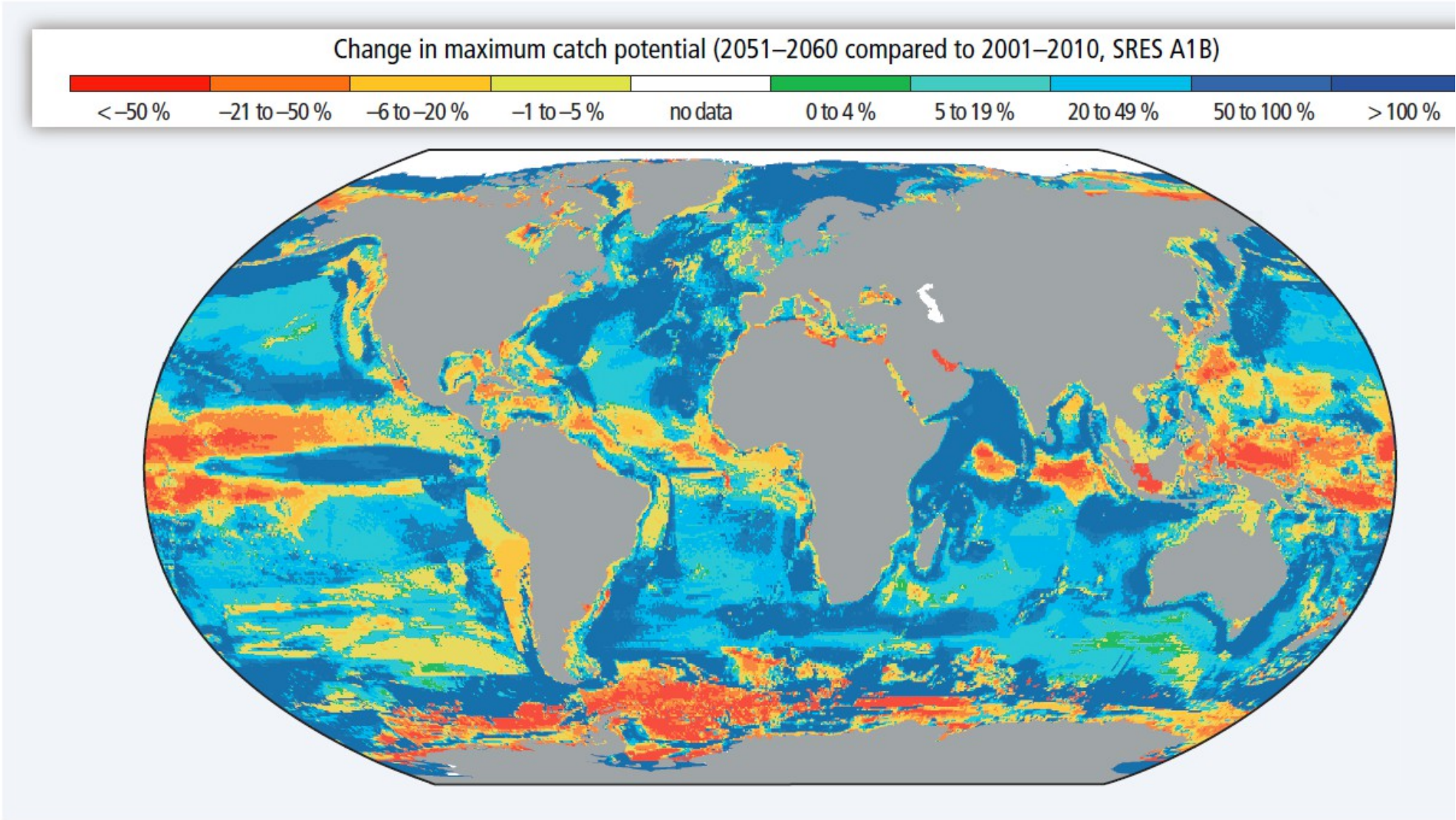
Accessible data, easily readable electronic format

"Feed" models, at both diagnostic and prognostic levels

Identify the most sensitive coastal ecosystems (biodiversity, fisheries, aquaculture, tourism, management)

OA is a multidisciplinary issue!!

(A)


Change in maximum catch potential (2051–2060 compared to 2001–2010, SRES A1B)
< –50 %
–21 to –50 %
–6 to –20 %
–1 to –5 %
no data
0 to 4 %
5 to 19 %
20 to 49 %
50 to 100 %
> 100 %