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Ocean Acidification & SIDS: the basics

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Photo: Yuna Zayasu

Photo: Ray Berkelman, AIMS

“When I dove into the water I entered a new world of which my wildest fantasies never could have imagined: corals, fish, and thousands of unfamiliar creatures in all possible shapes and colors of the rainbow - it was a tumbling experience.”

A.Andersson, Tonga, March 1997

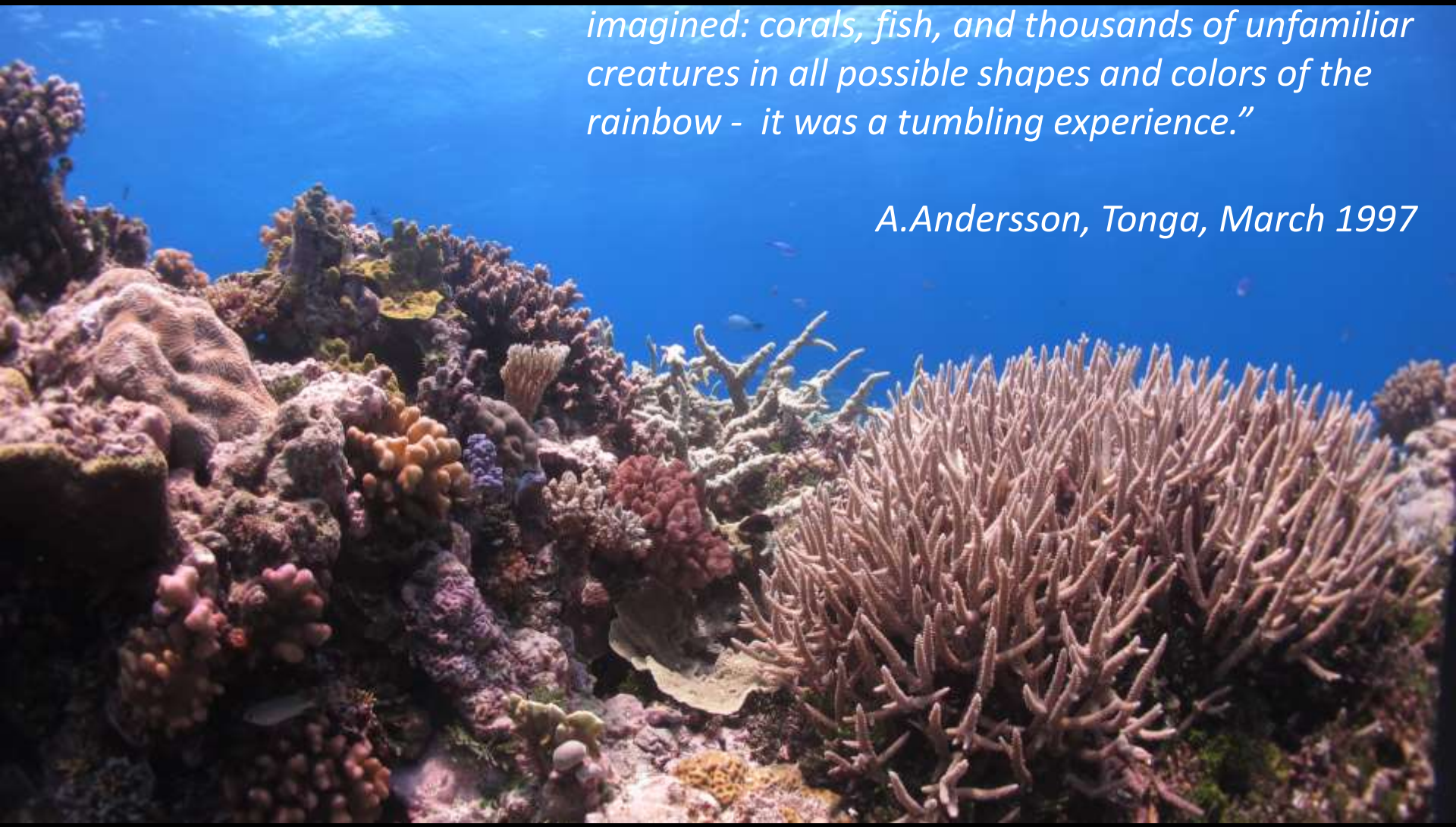


Photo: Ray Berkelman, AIMS

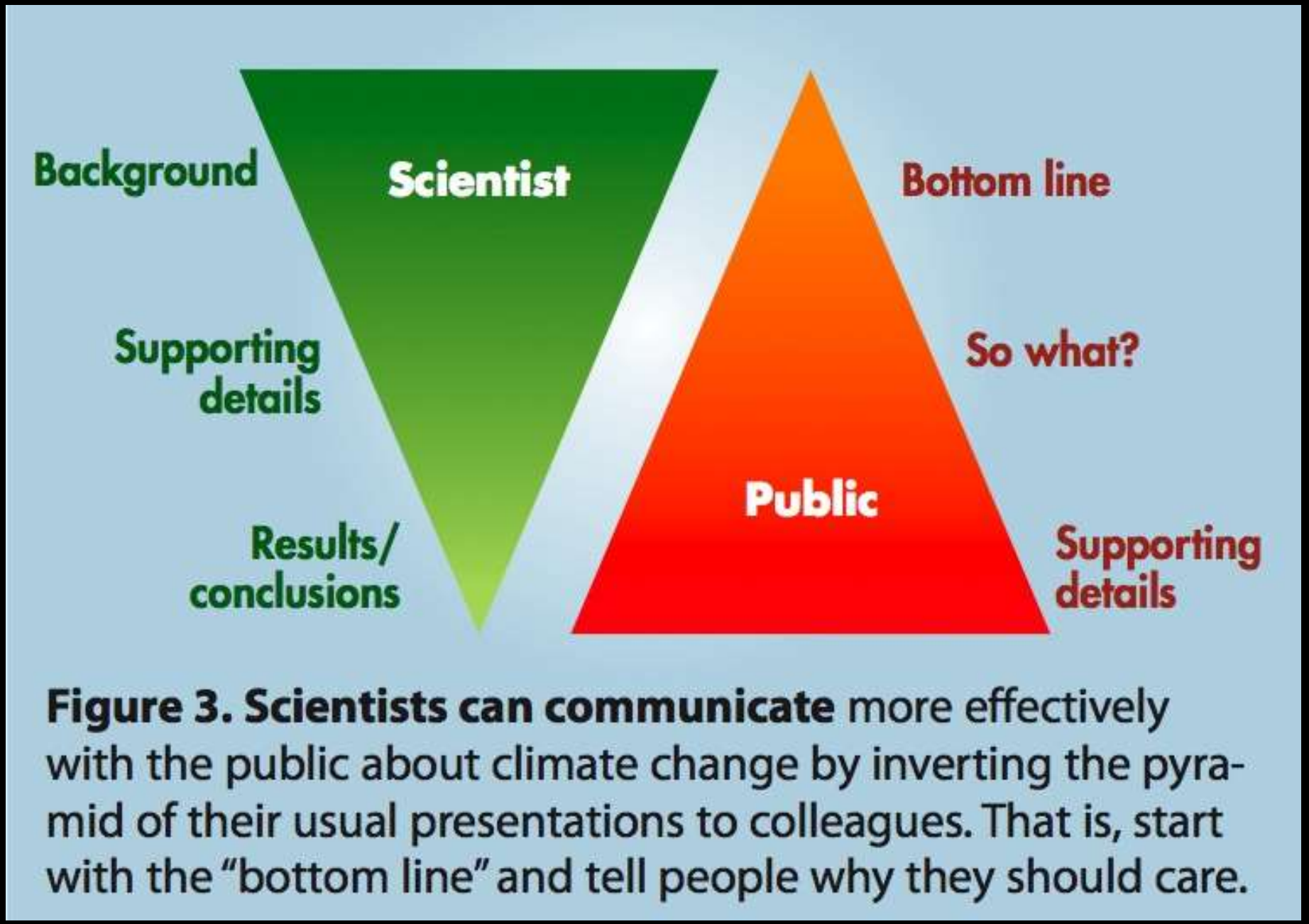


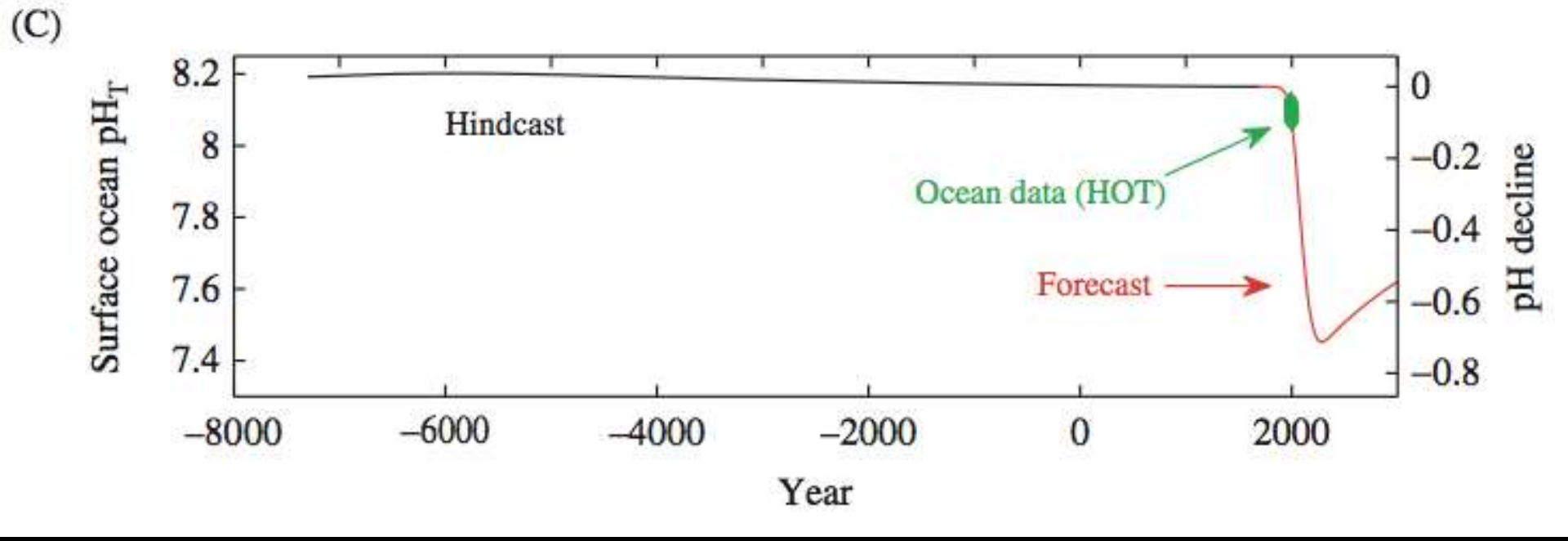
Figure 3. Scientists can communicate more effectively with the public about climate change by inverting the pyramid of their usual presentations to colleagues. That is, start with the "bottom line" and tell people why they should care.

Sommerville and Hassol 2011

Bottom line:

If we do not do anything about ocean acidification we will experience an OA hangover for 100s to 1000s of years!

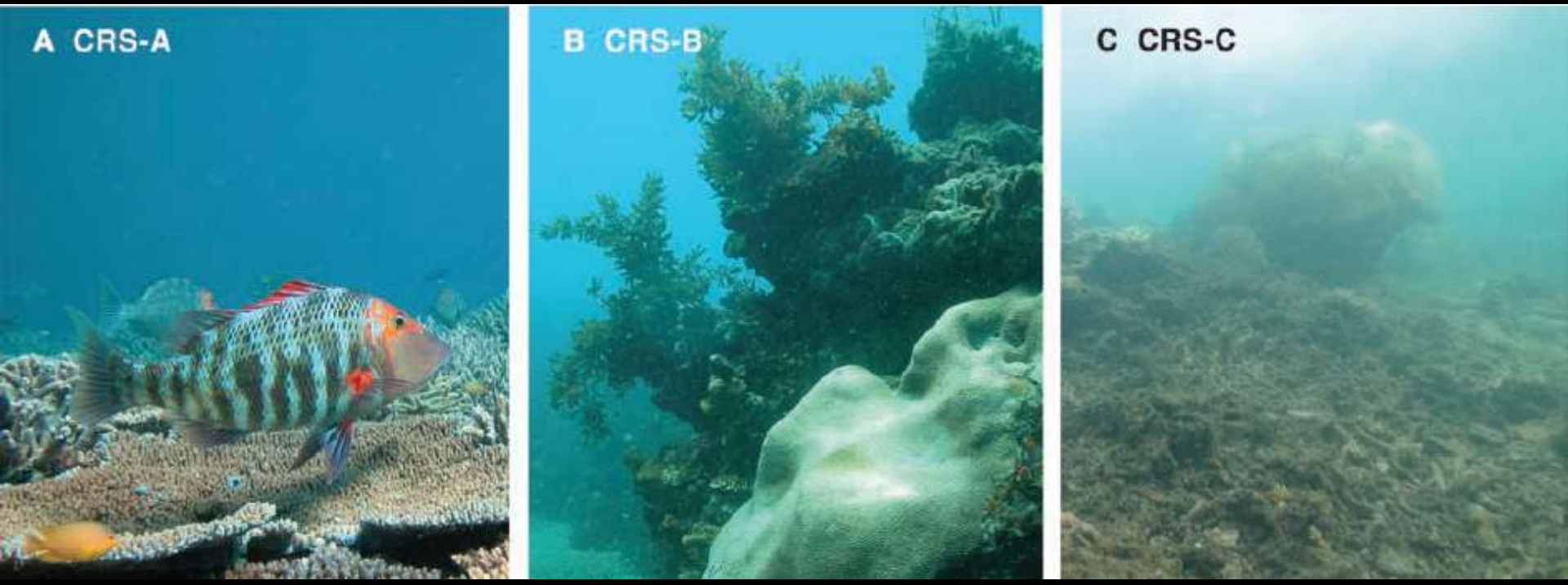
Ocean chemistry is changing rapidly and it will take 100s to 1000s of years to restore the ocean's acid-base balance



Zeebe & Ridgwell 2011

We do not fully understand the potential biological and ecological impacts of OA but…

…coral reefs are likely to undergo phase shifts, decreased biodiversity, and net erosion (i.e., no reef growth)…



Hoegh-Guldberg et al. 2007

Ocean acidification & warming

….which will negatively influence services provided by coral reefs…

Jackson et al. 2014

What can we do about ocean acidification?

Global scale:

- Slow down the rate of CO_2 emissions
- Monitoring & research (e.g., GOA-ON)

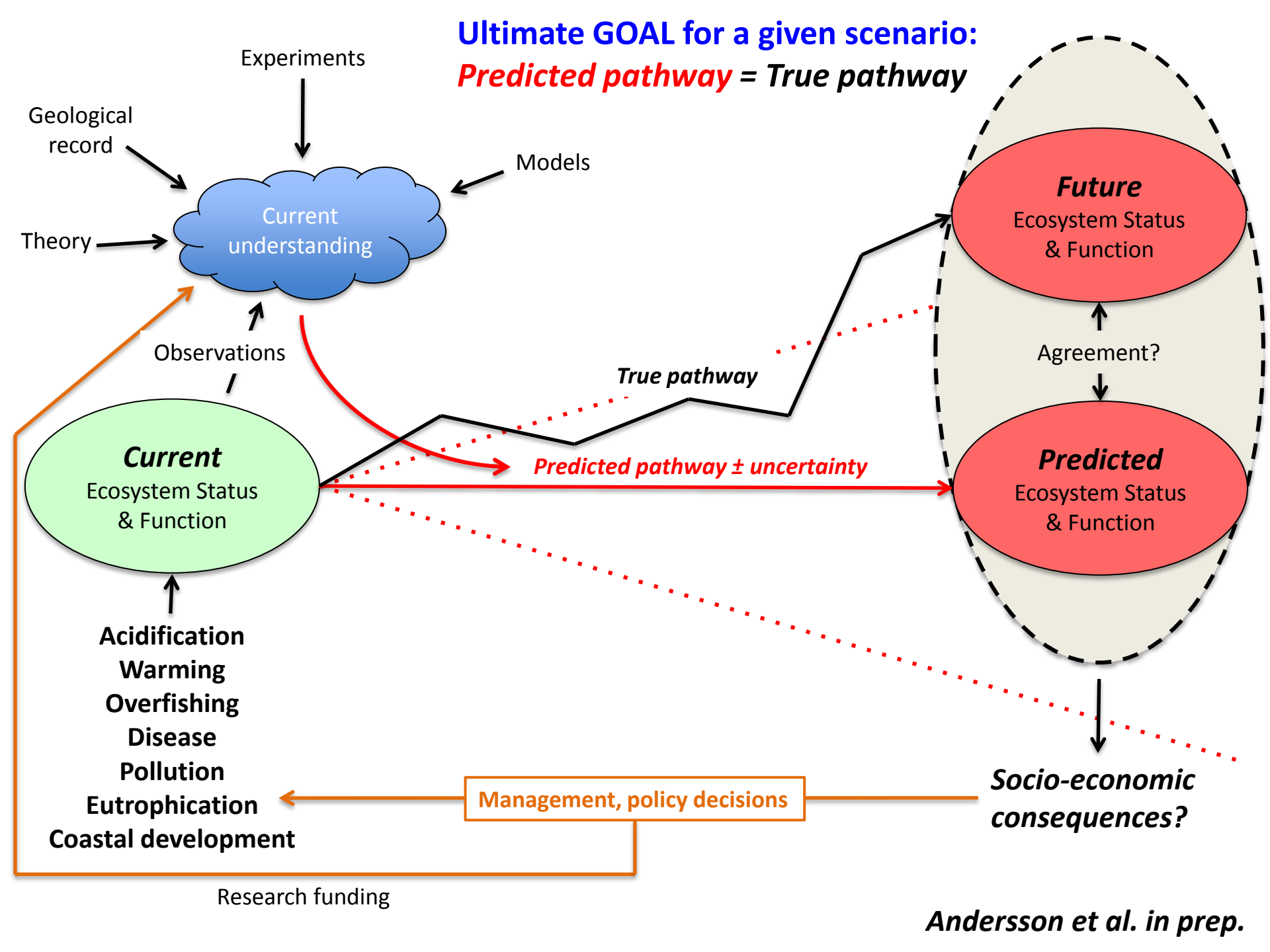
Regional scale:

Smart decisions and actions that address:

- Overfishing
- Coastal development
- Pollution, Sedimentation & Eutrophication
- Monitoring & research -> management

….we don’t want to just monitor the demise of coral reefs…

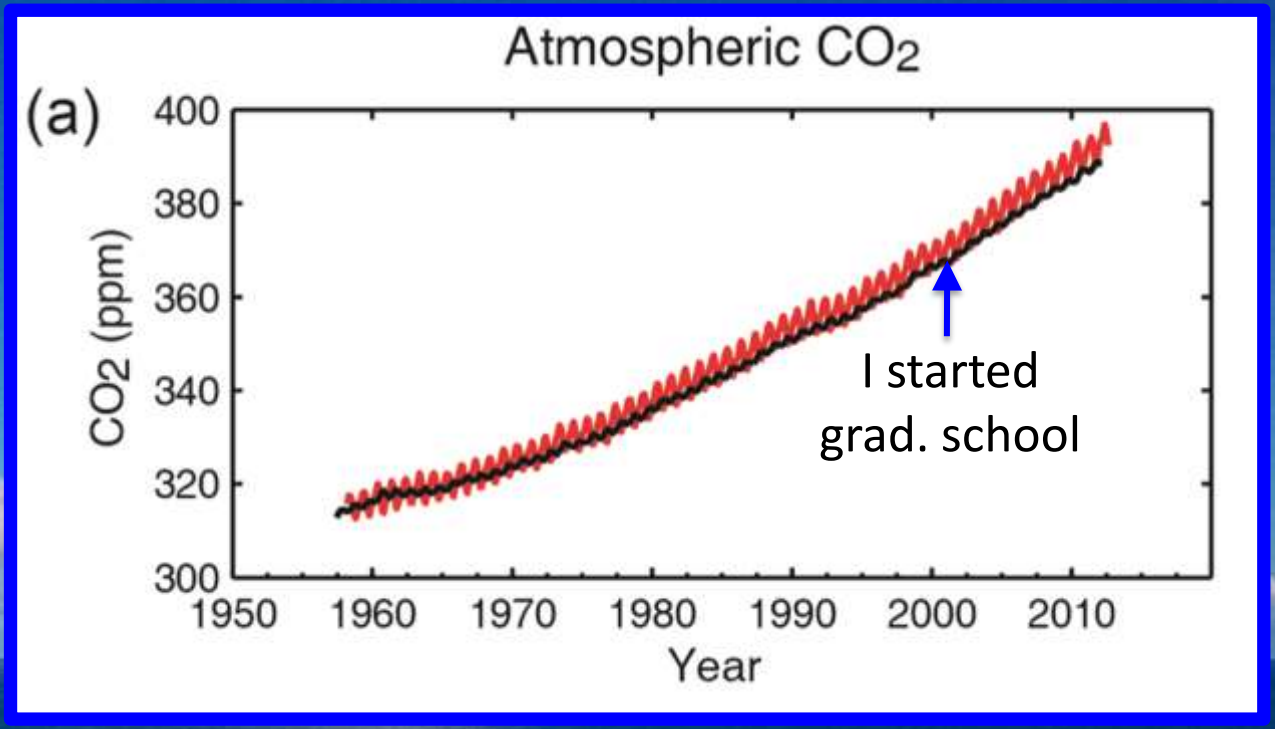
Jackson et al. 2014


Ultimate GOAL for a given scenario:
Predicted pathway = True pathway
Experiments
Geological record
Models
Theory
Current understanding
Observations
Future
Ecosystem Status & Function
Agreement?
True pathway
Current
Ecosystem Status & Function
Predicted pathway ± uncertainty
Predicted
Ecosystem Status & Function
Acidification
Warming
Overfishing
Disease
Pollution
Eutrophication
Coastal development
Management, policy decisions
Socio-economic consequences?
Research funding
Andersson et al. in prep.

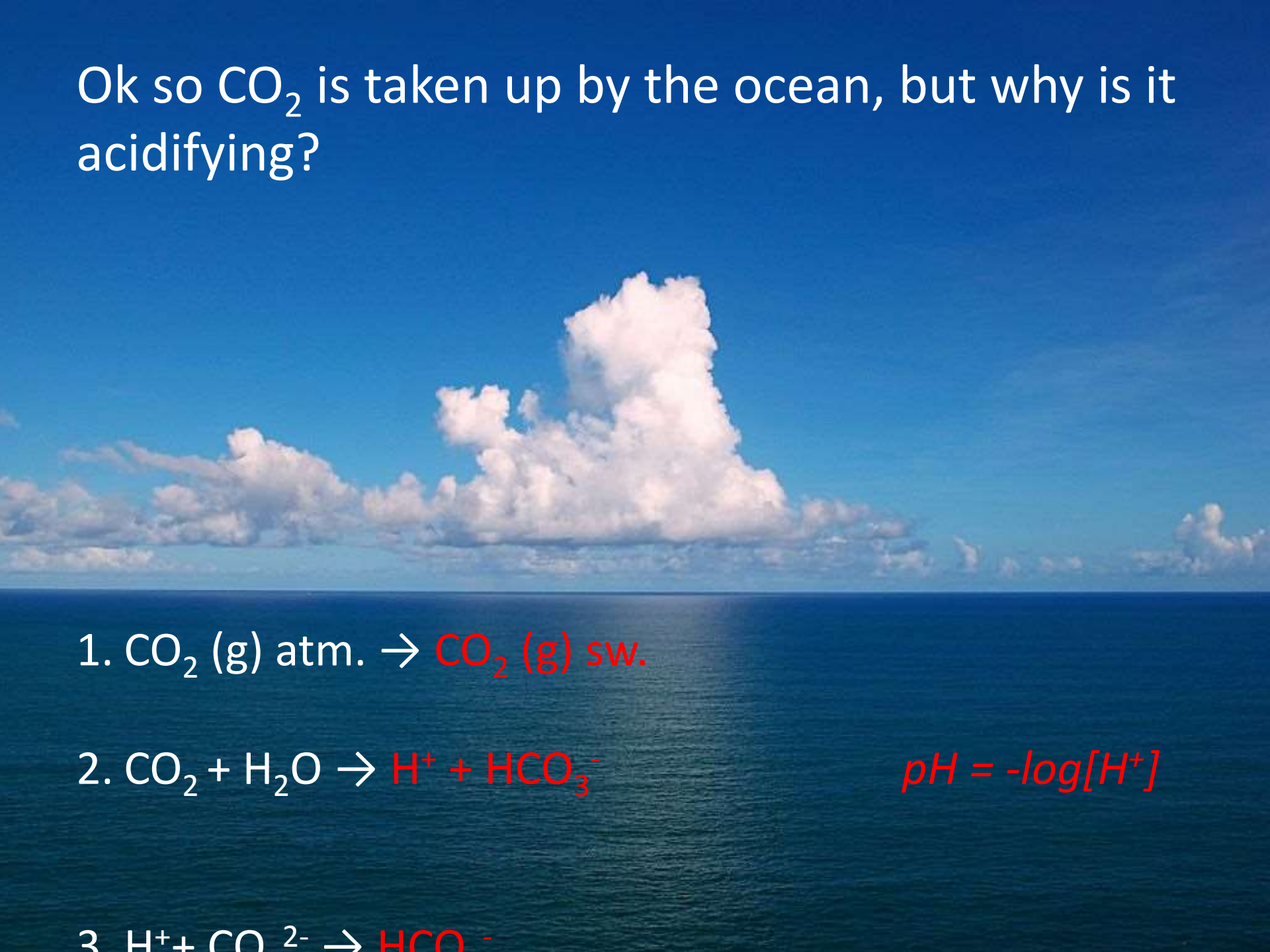
What is ocean acidification?

What is ocean acidification?

CO_2



$$CO_2 + H_2O = H_2CO_3 = HCO_3^- + H^+ = CO_3^{2-} + 2H^+$$



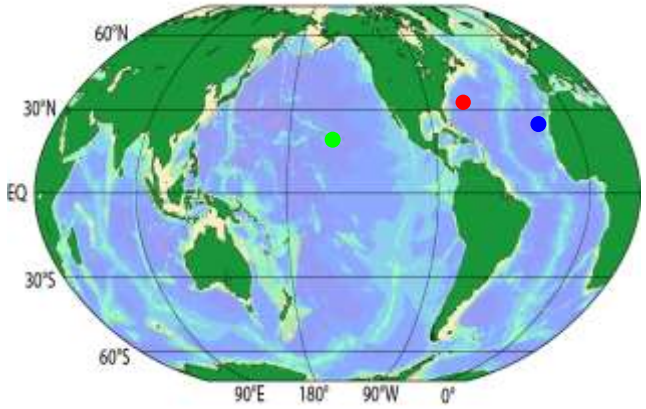
Ok so CO_2 is taken up by the ocean, but why is it acidifying?

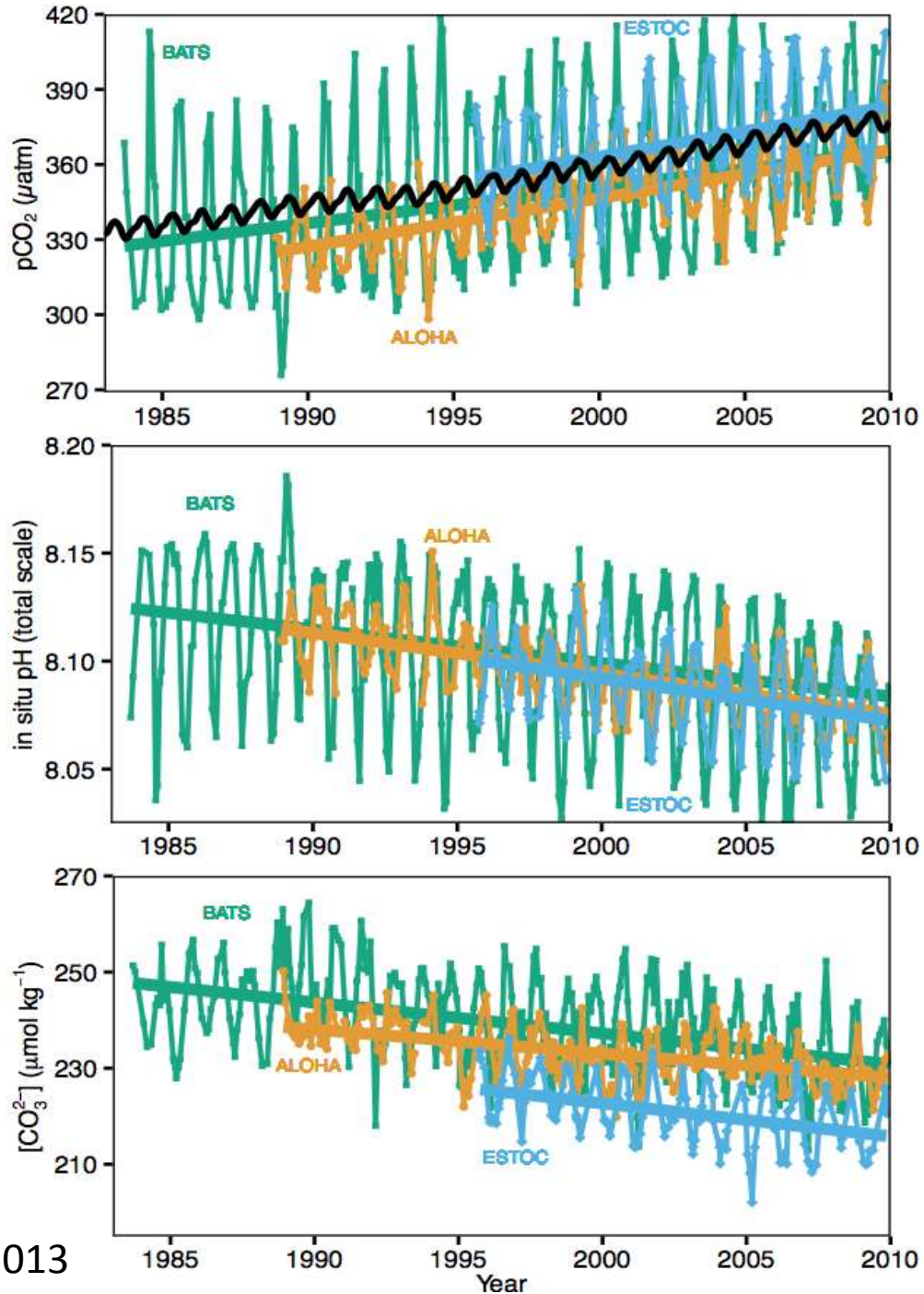
1. CO_2 (g) atm. → CO_2 (g) sw.

2. $CO_2 + H_2O \rightarrow H^+ + HCO_3^-$ $pH = -log[H^+]$

3. $H^+ + CO_3^{2-} \rightarrow HCO_3^-$

What is the evidence for ocean acidification?





IPCC 2013

Do we have evidence for ocean acidification within coral reefs?

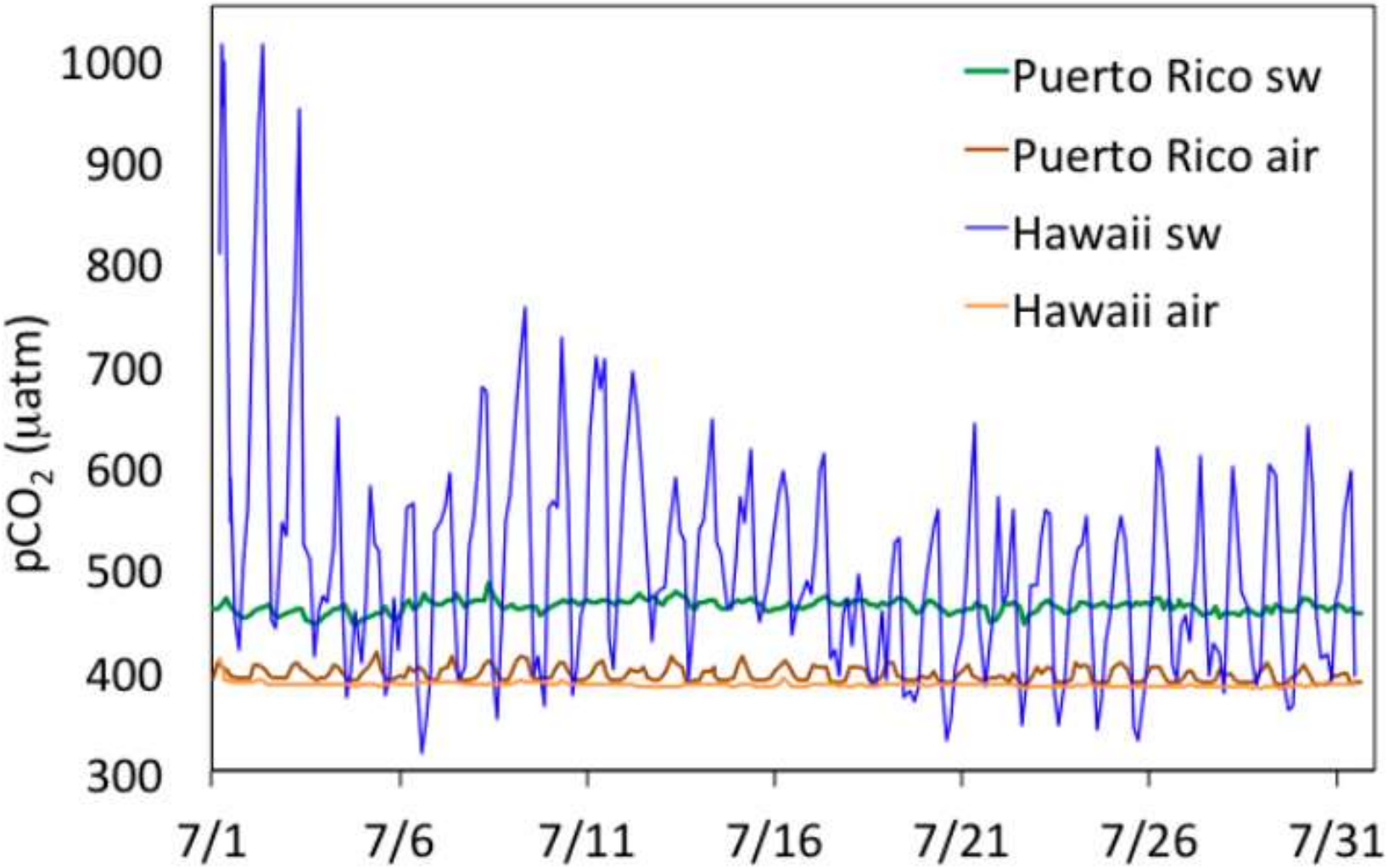
Photo: Yuna Zayasu

Photosynthesis - Respiration

$$CO_2 + H_2O = CH_2O + O_2$$

Calcification - $CaCO_3$ dissolution

$$Ca^{2+} + 2HCO_3^- = CaCO_3 + CO_2 + H_2O$$



Andersson & Mackenzie 2012

NOAA PMEL coral reef pCO_2 buoy network

Australia
Bermuda
Chuuk
Florida
Hawaii
Puerto Rico

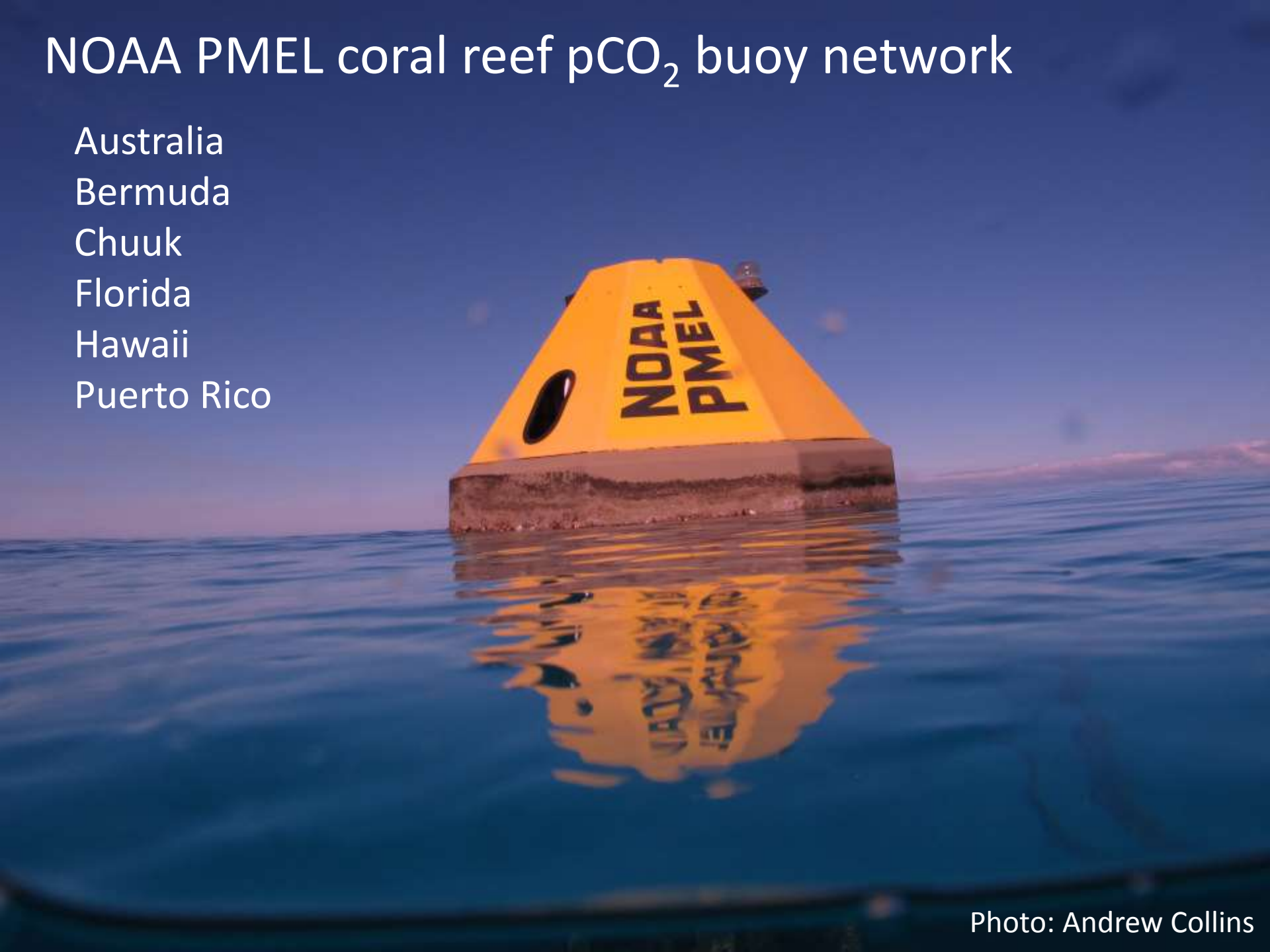
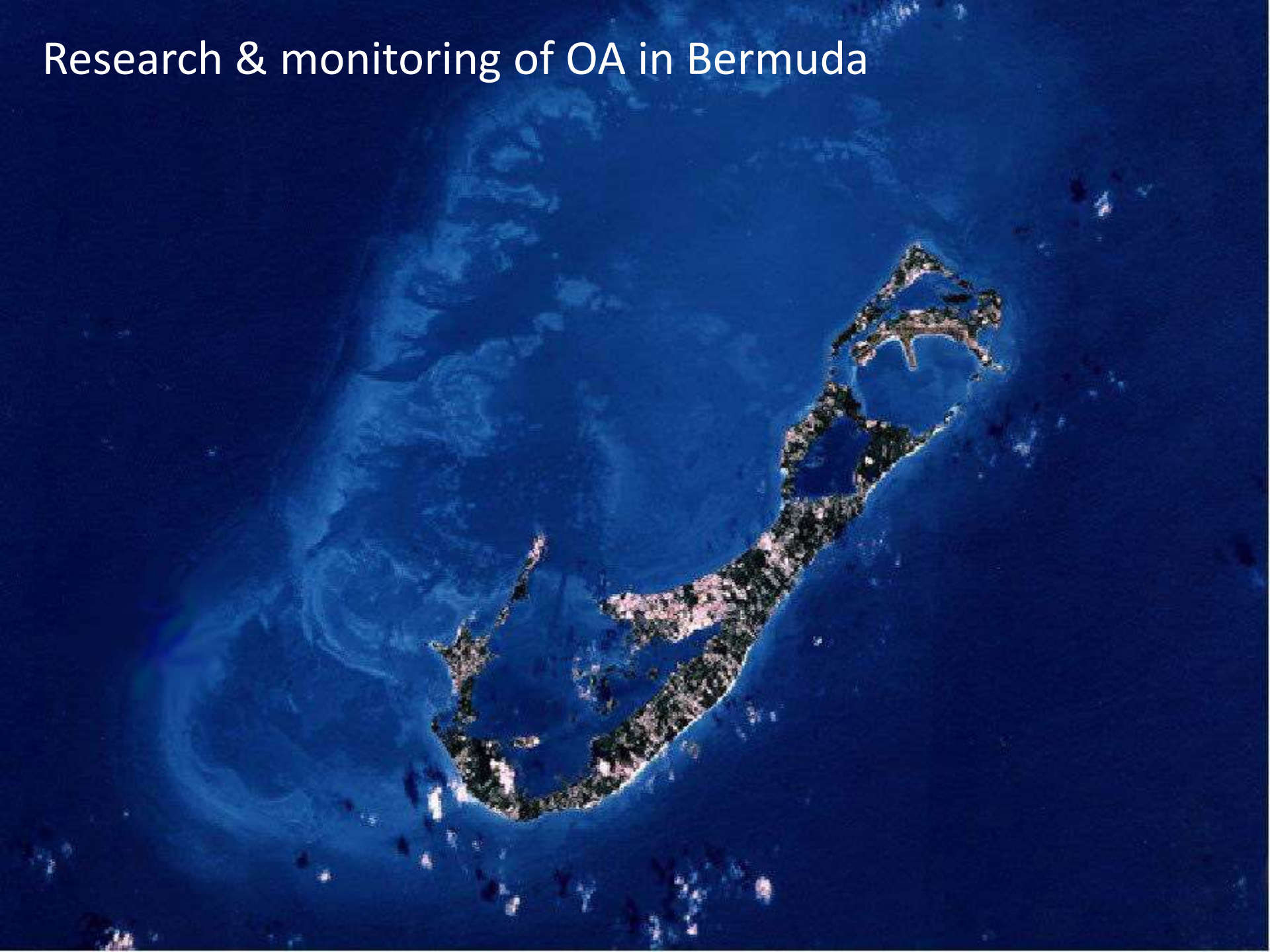
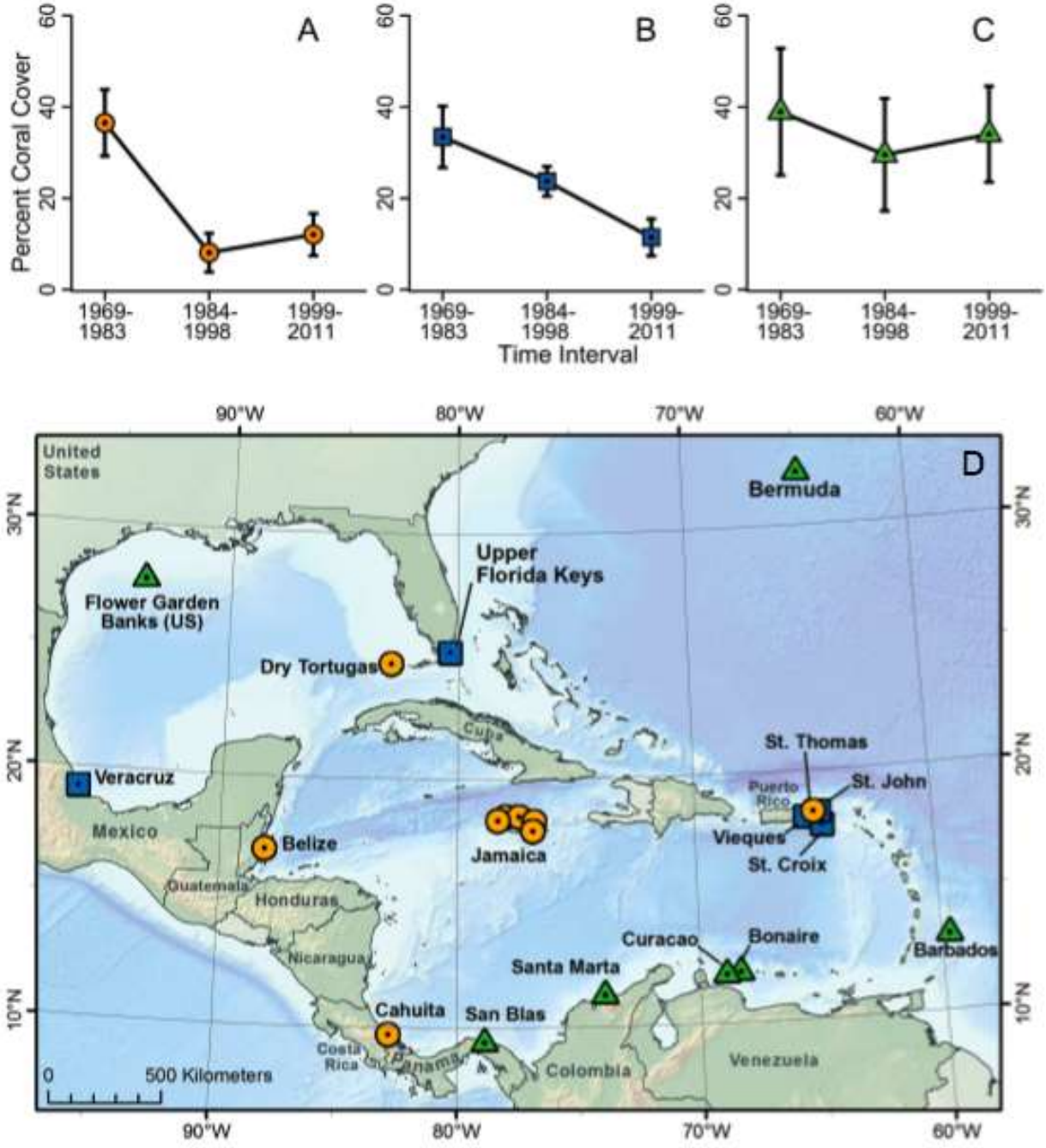


Photo: Andrew Collins

Research & monitoring of OA in Bermuda





Jackson et al. 2014

BErmuda ocean Acidification and Coral reef iNvestigation - BEACON

Seawater chemistry & biogeochemistry

- OA observing buoys
- Reef monthly time series
- Reef spatial surveys
- Bermuda Atlantic Time Series

  (T, S, DIC, TA, nutrients)

Biological & biogeochemical measurements

- *In situ* coral calcification
- *Ex situ* coral calcification
- Net Community Calcification
- Net Ecosystem Calcification
- Community composition
- Coral physiology
  - Mineralogy
  - Org. matrix
  - Molecular
- $CaCO_3$ Accretion Units (CAU)
- Bioerosion
- $CaCO_3$ sediment dissolution

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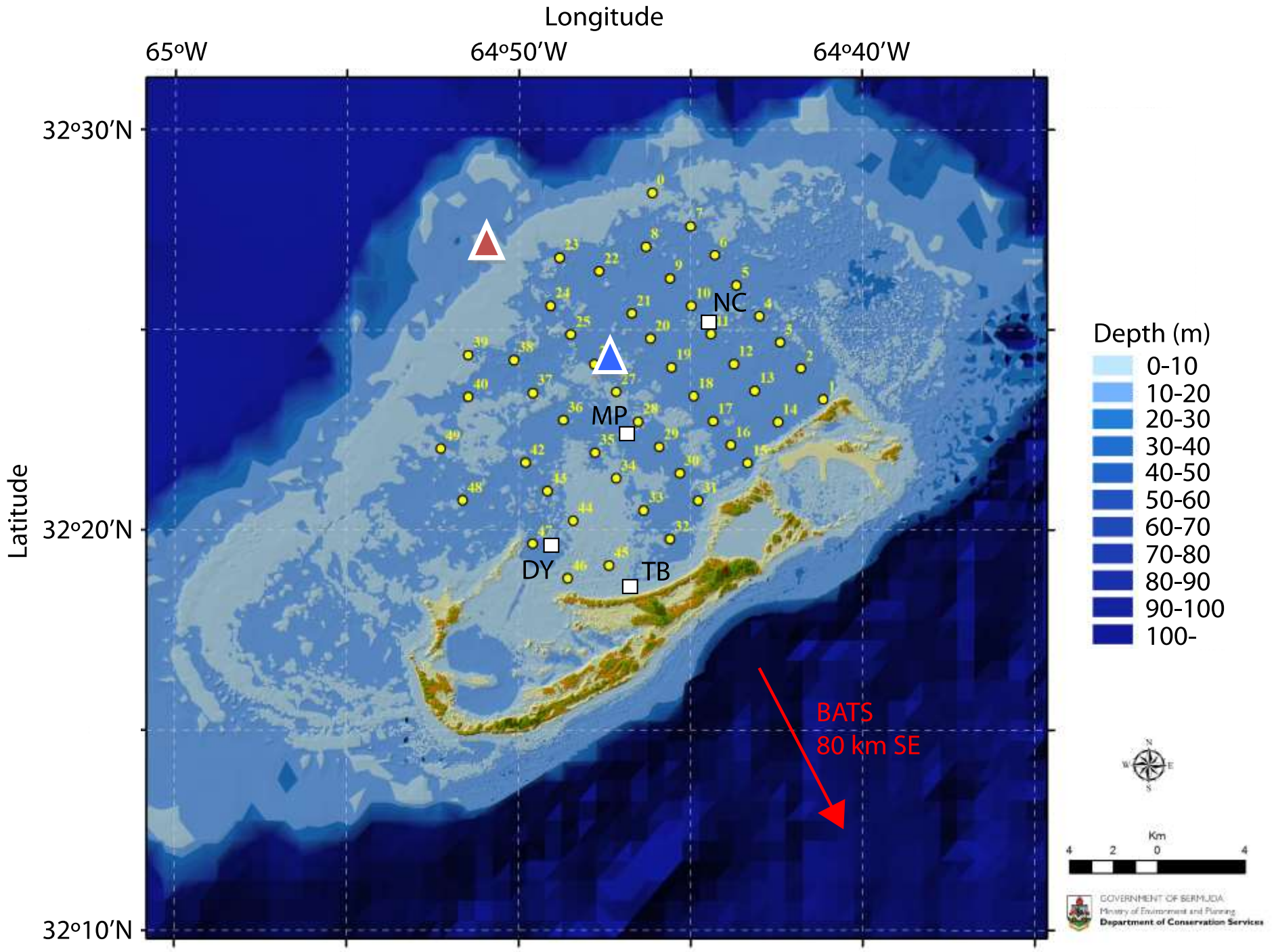
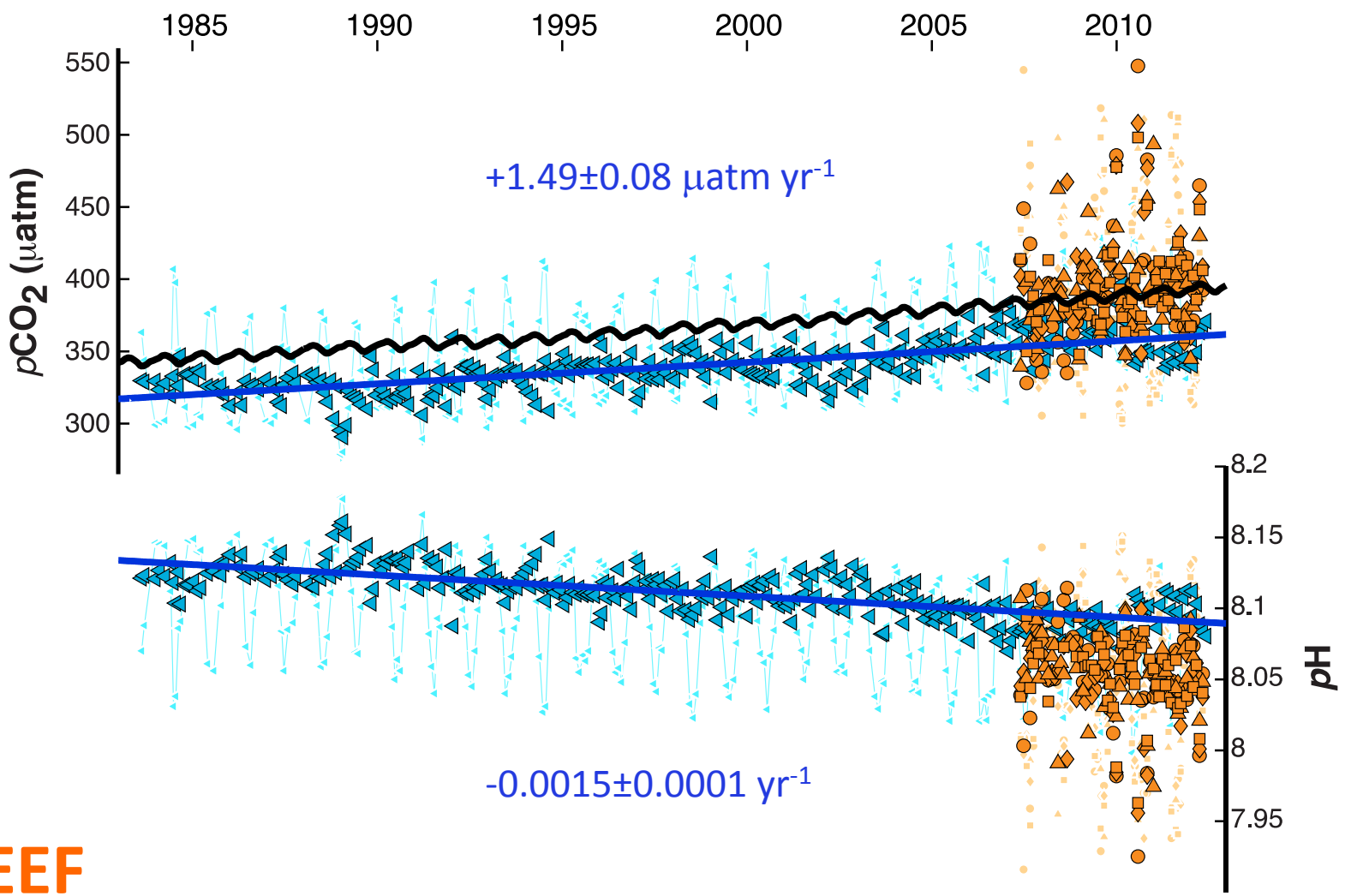
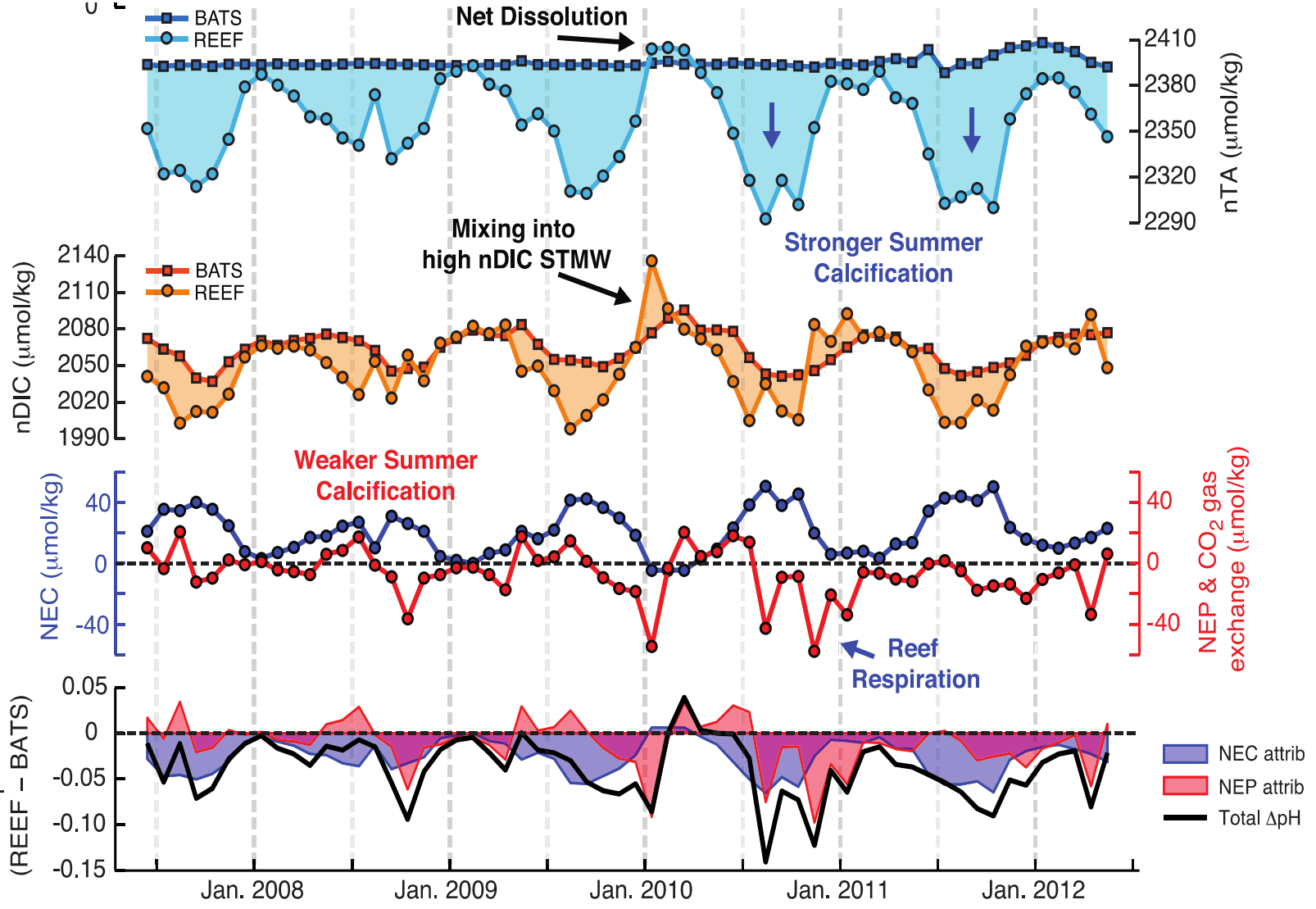

Longitude
65°W
64°50'W
64°40'W
32°30'N
32°20'N
32°10'N
Latitude
NC
MP
DY
TB
BATS
80 km SE
Depth (m)
0-10
10-20
20-30
30-40
40-50
50-60
60-70
70-80
80-90
90-100
100-
Km
4 2 0 4
GOVERNMENT OF BERMUDA
Ministry of Environment and Planning
Department of Conservation Services

Evidence of ocean acidification



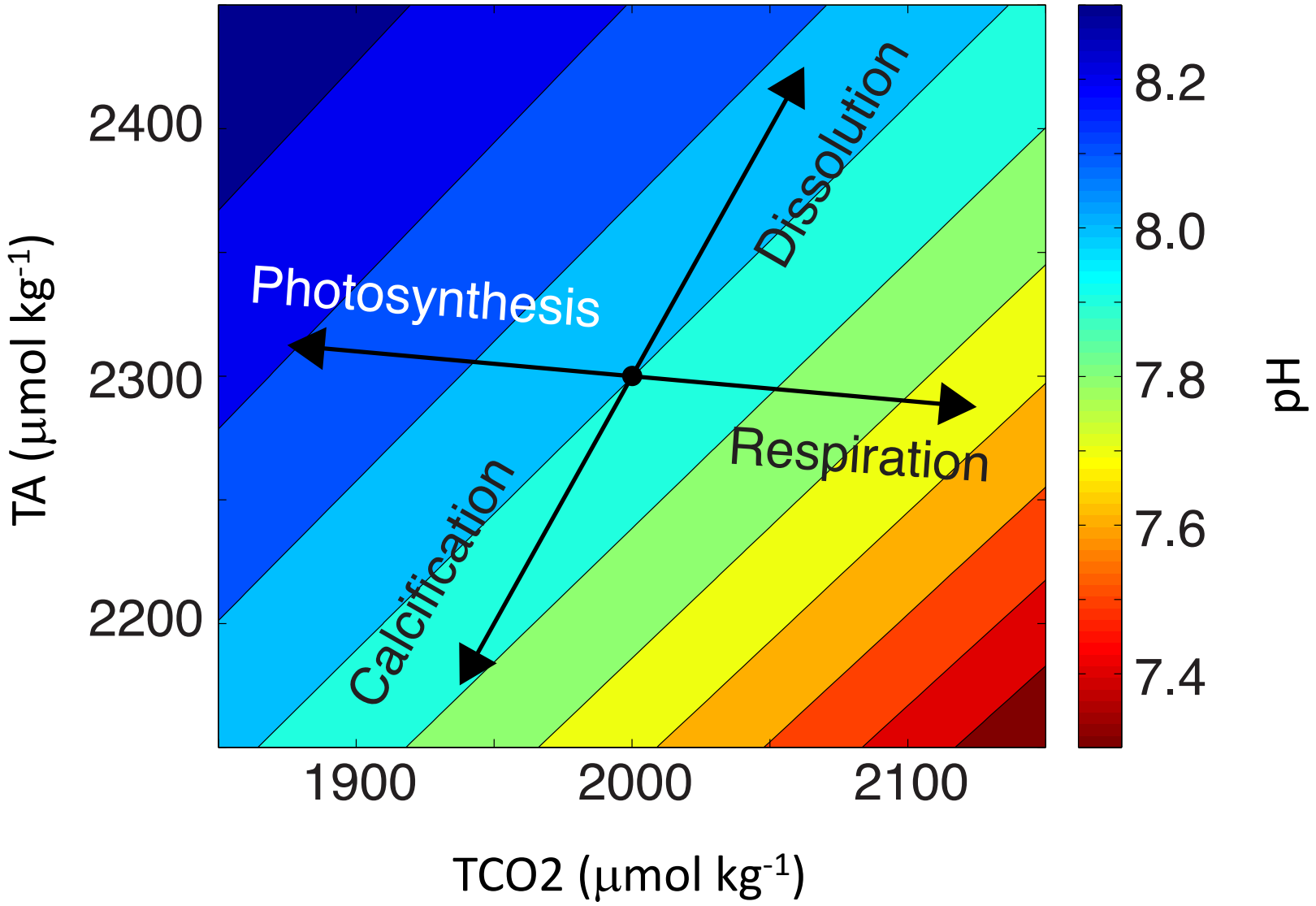
Yeakel et al. *in review*

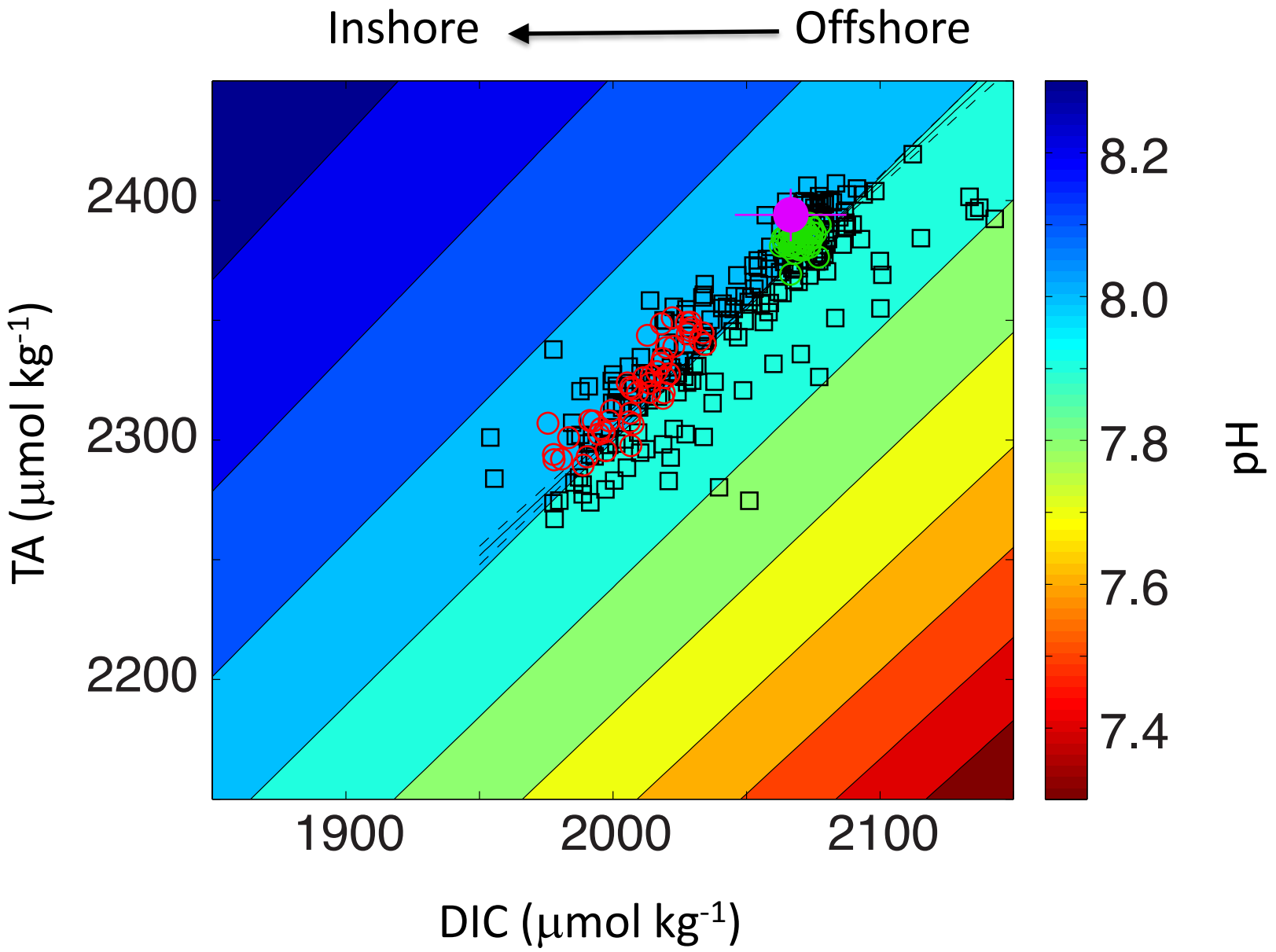
Net Ecosystem Calcification and Organic Carbon production (NEC & NEP)

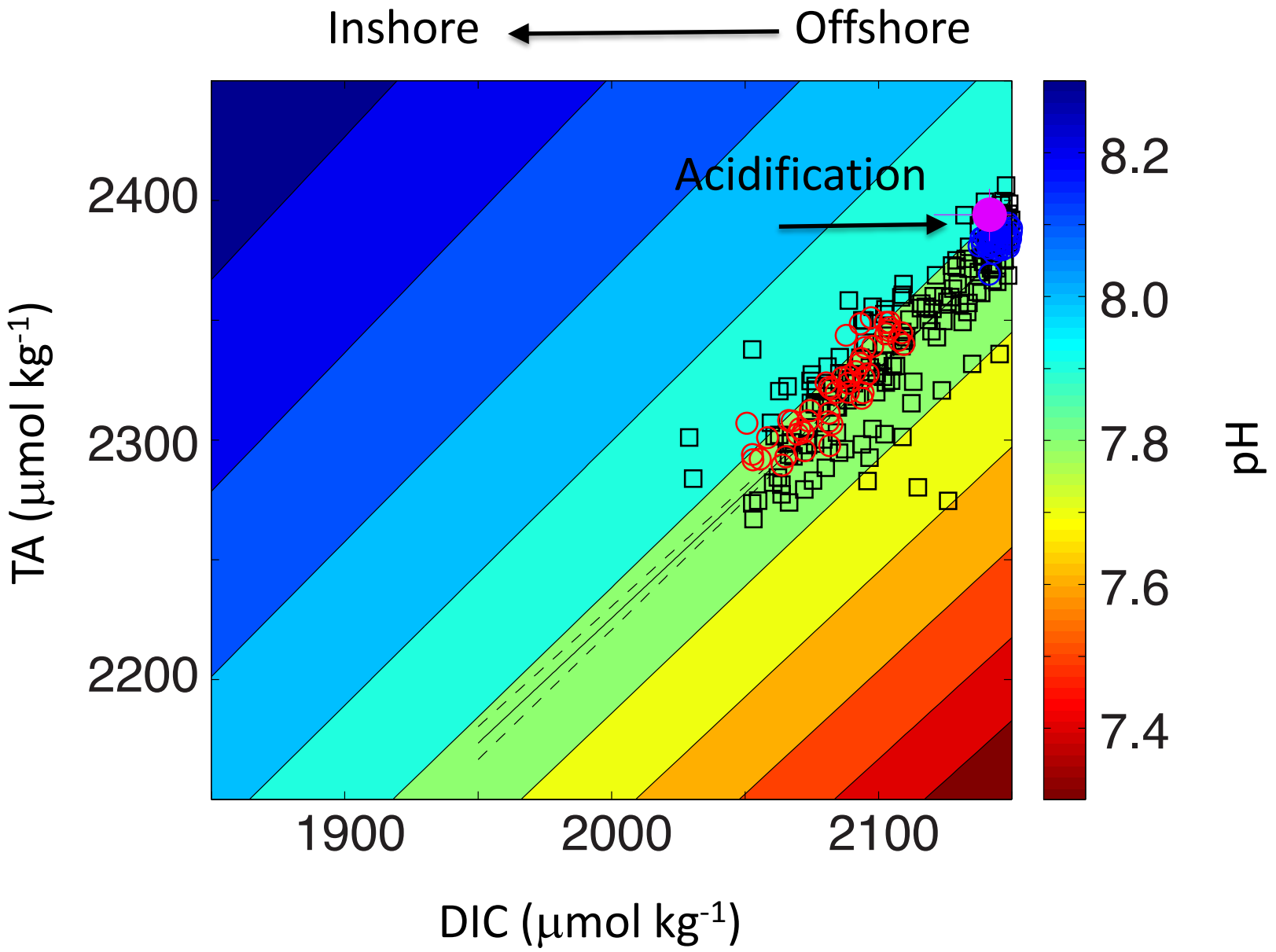


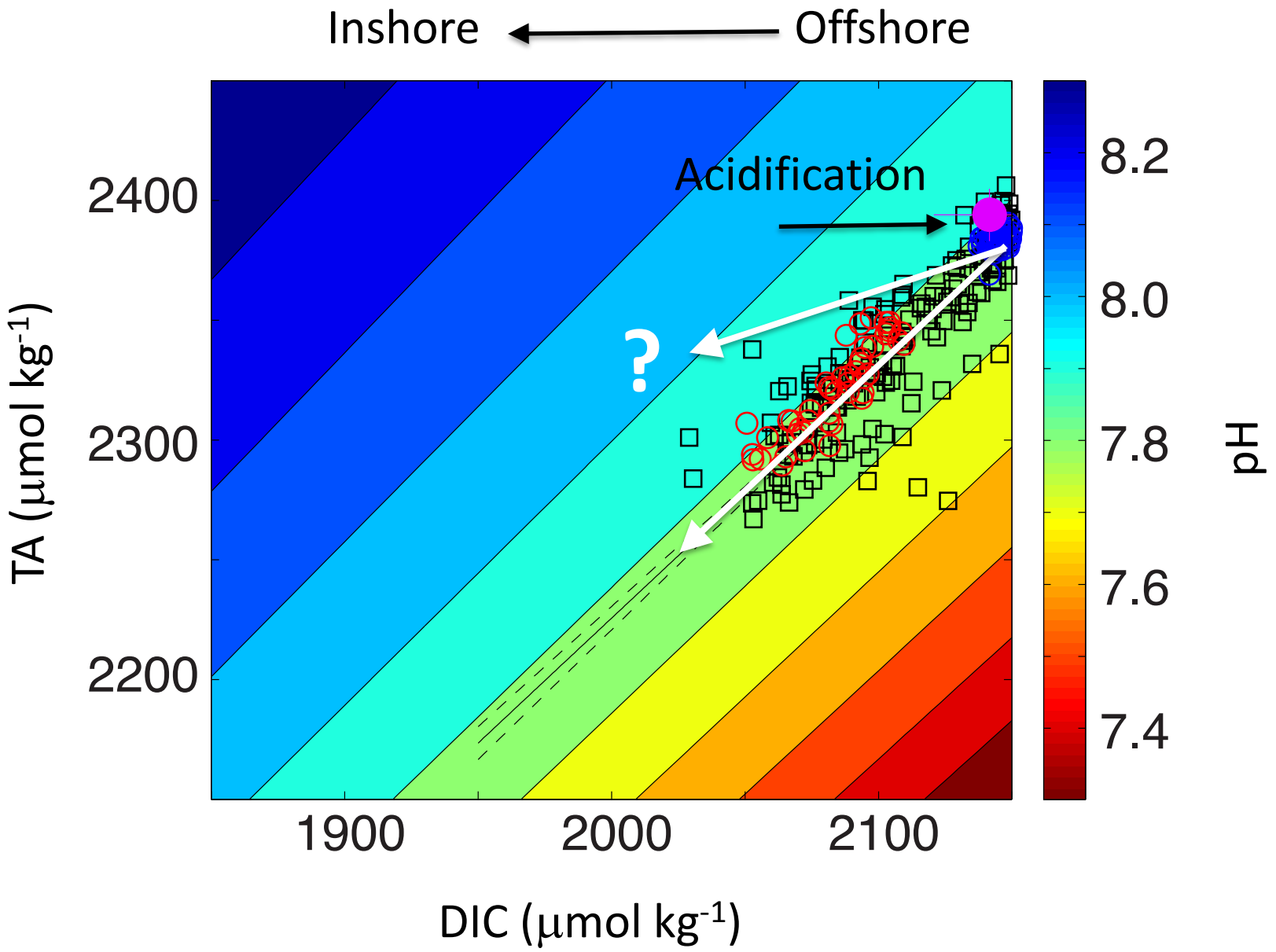
Yeakel et al. *in review*

Taking the pulse of coral reefs using seawater chemistry…



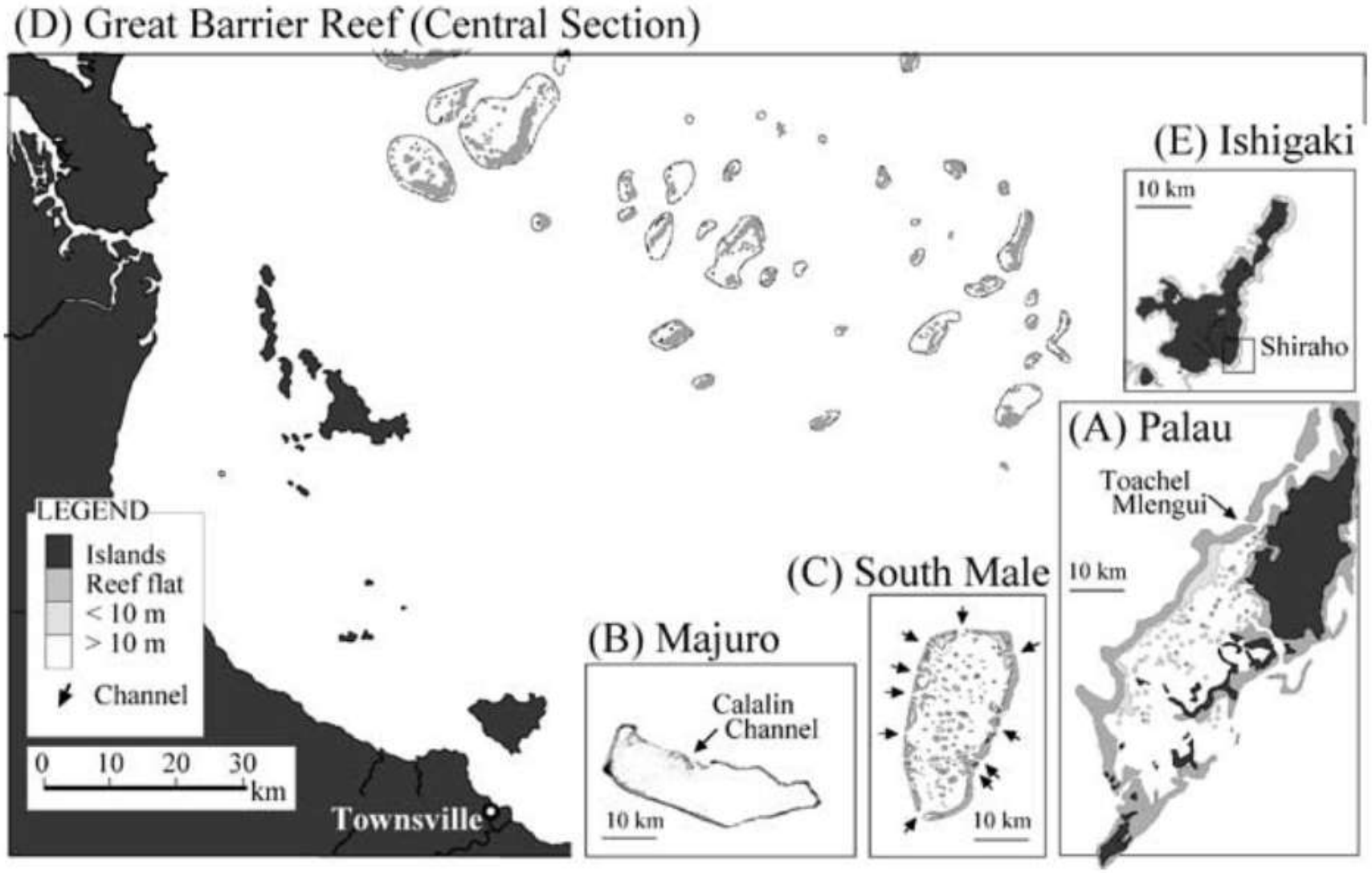

Inshore
Offshore
2400
2300
2200
TA (µmol kg-1)
1900
2000
2100
DIC (µmol kg-1)
8.2
8.0
7.8
7.6
7.4
pH


Inshore
Offshore
Acidification
2400
2300
2200
TA (µmol kg-1)
1900
2000
2100
DIC (µmol kg-1)
8.2
8.0
7.8
7.6
7.4
pH

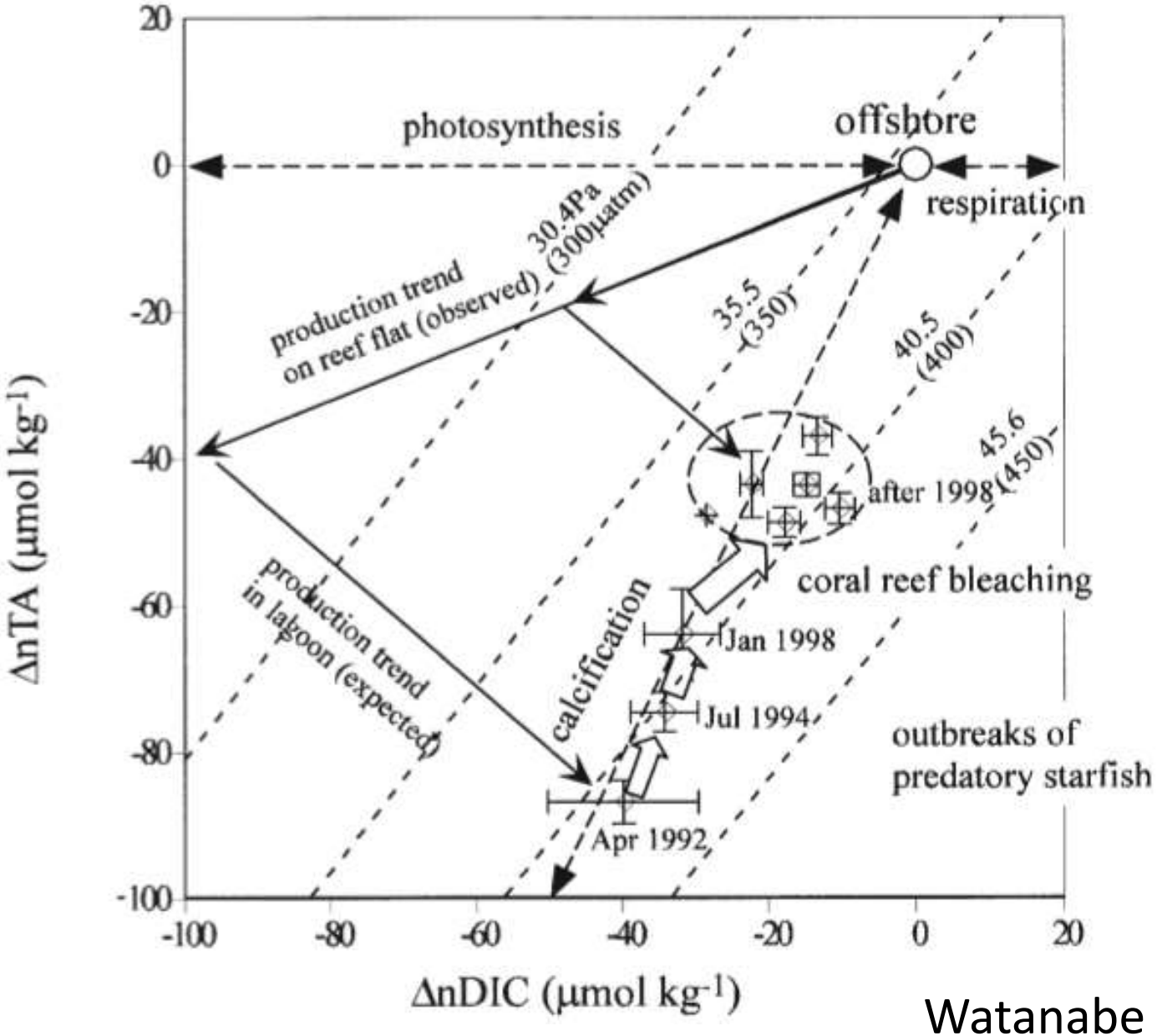

Inshore
Offshore
Acidification
?
2400
2300
2200
TA (µmol kg-1)
1900
2000
2100
DIC (µmol kg-1)
8.2
8.0
7.8
7.6
7.4
pH

Carbon budget of coral reef systems: an overview of observations in fringing reefs, barrier reefs and atolls in the Indo-Pacific regions

Suzuki & Kawahata 2003

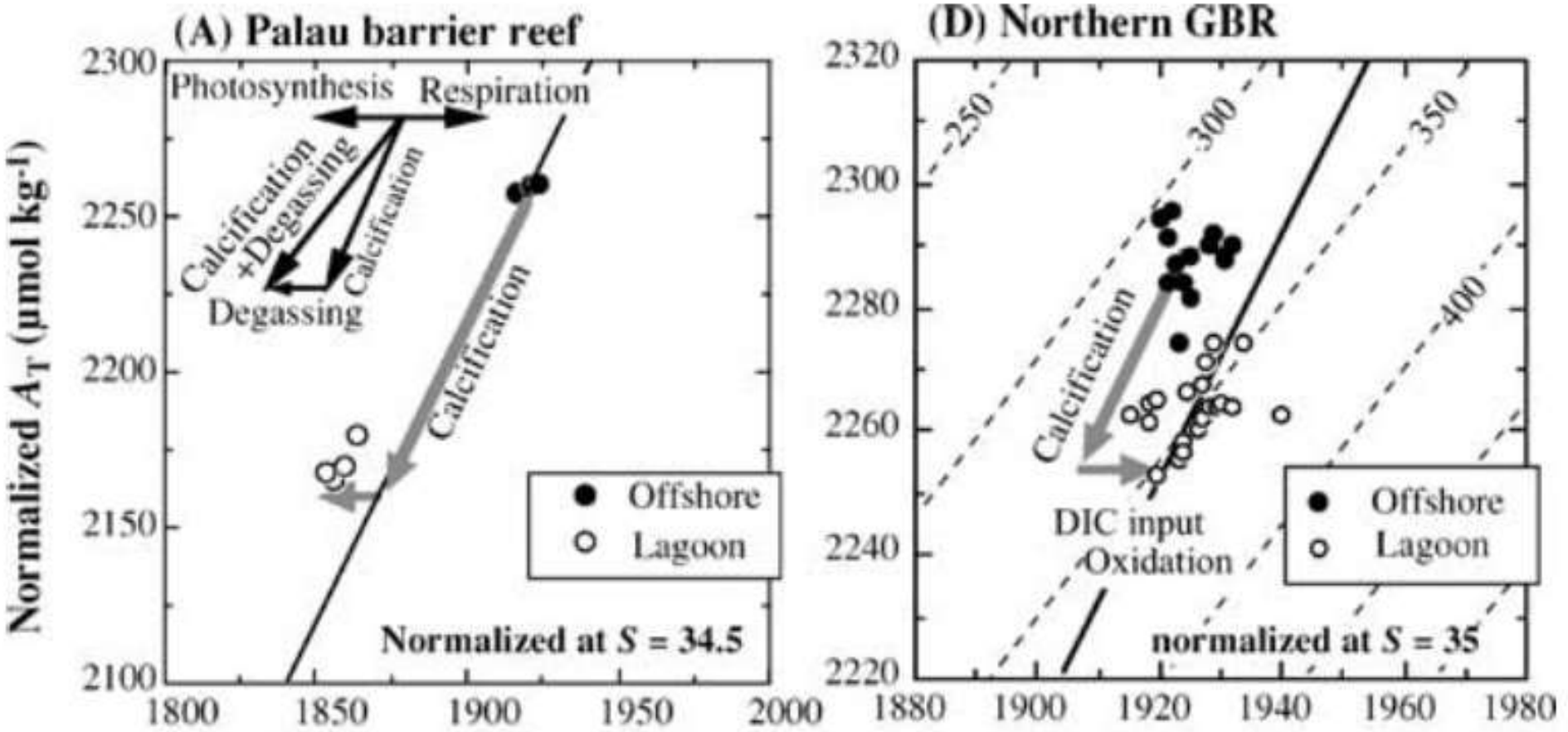


Data from Palau…

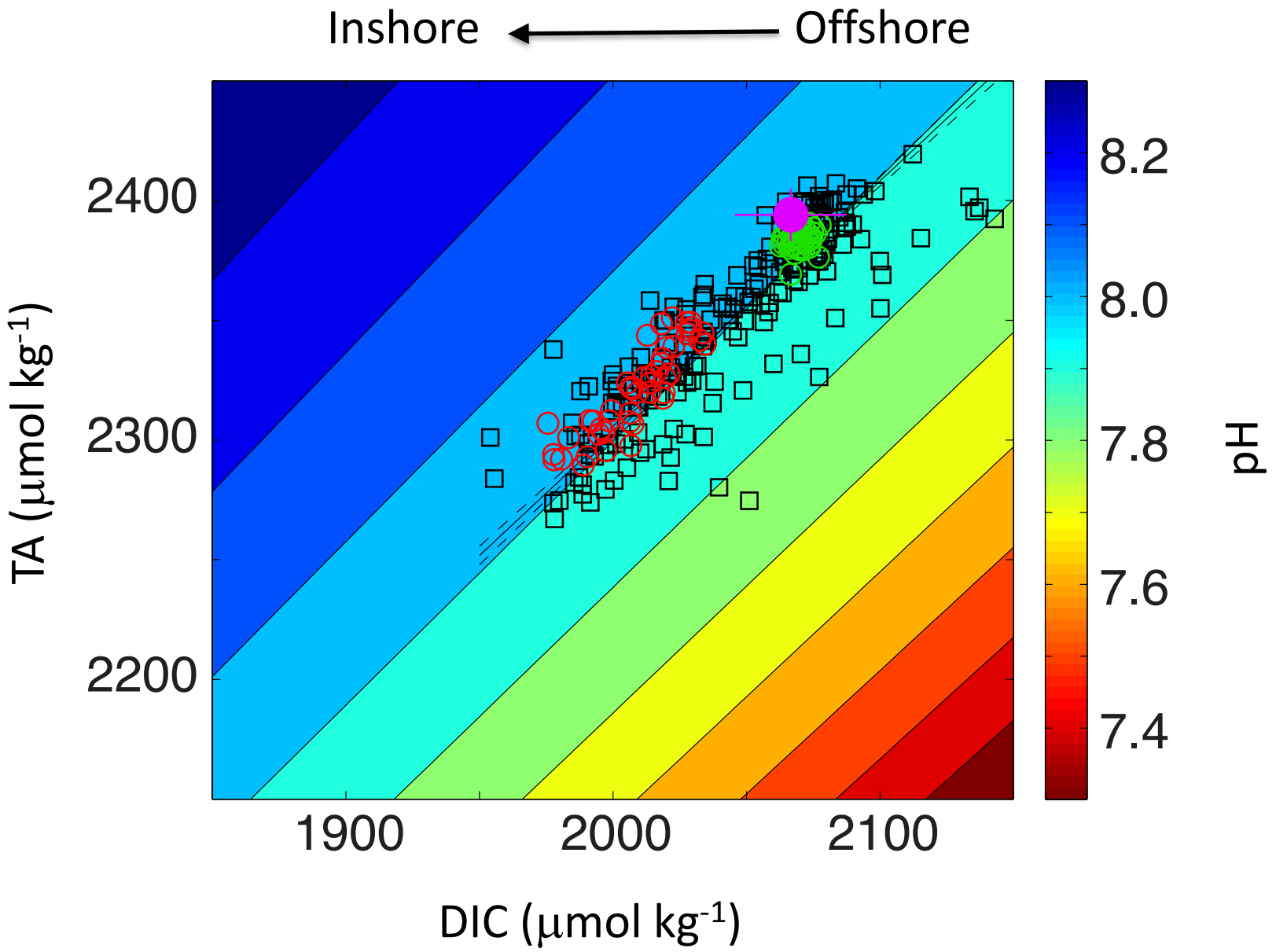


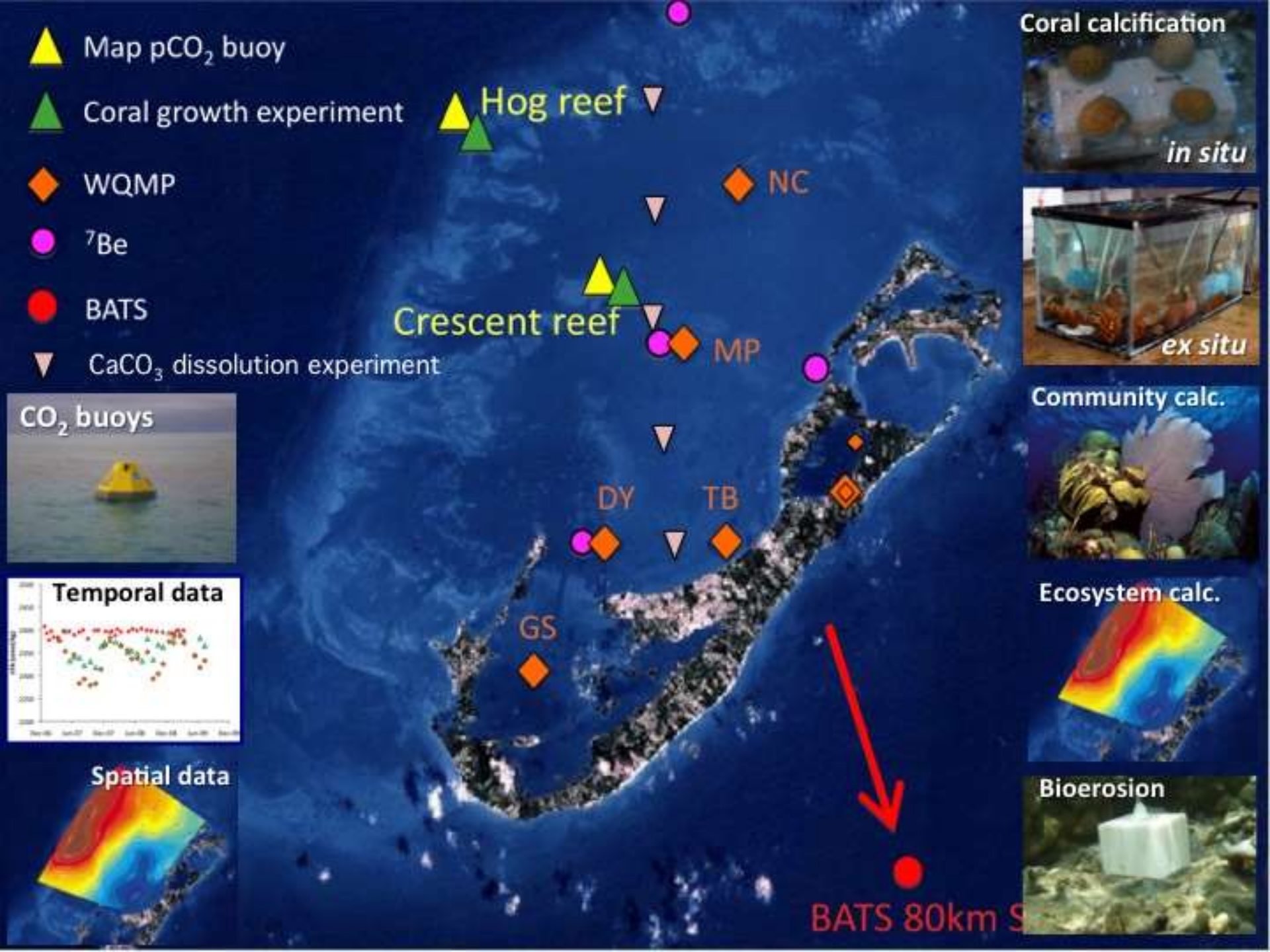
Watanabe et al. 2006

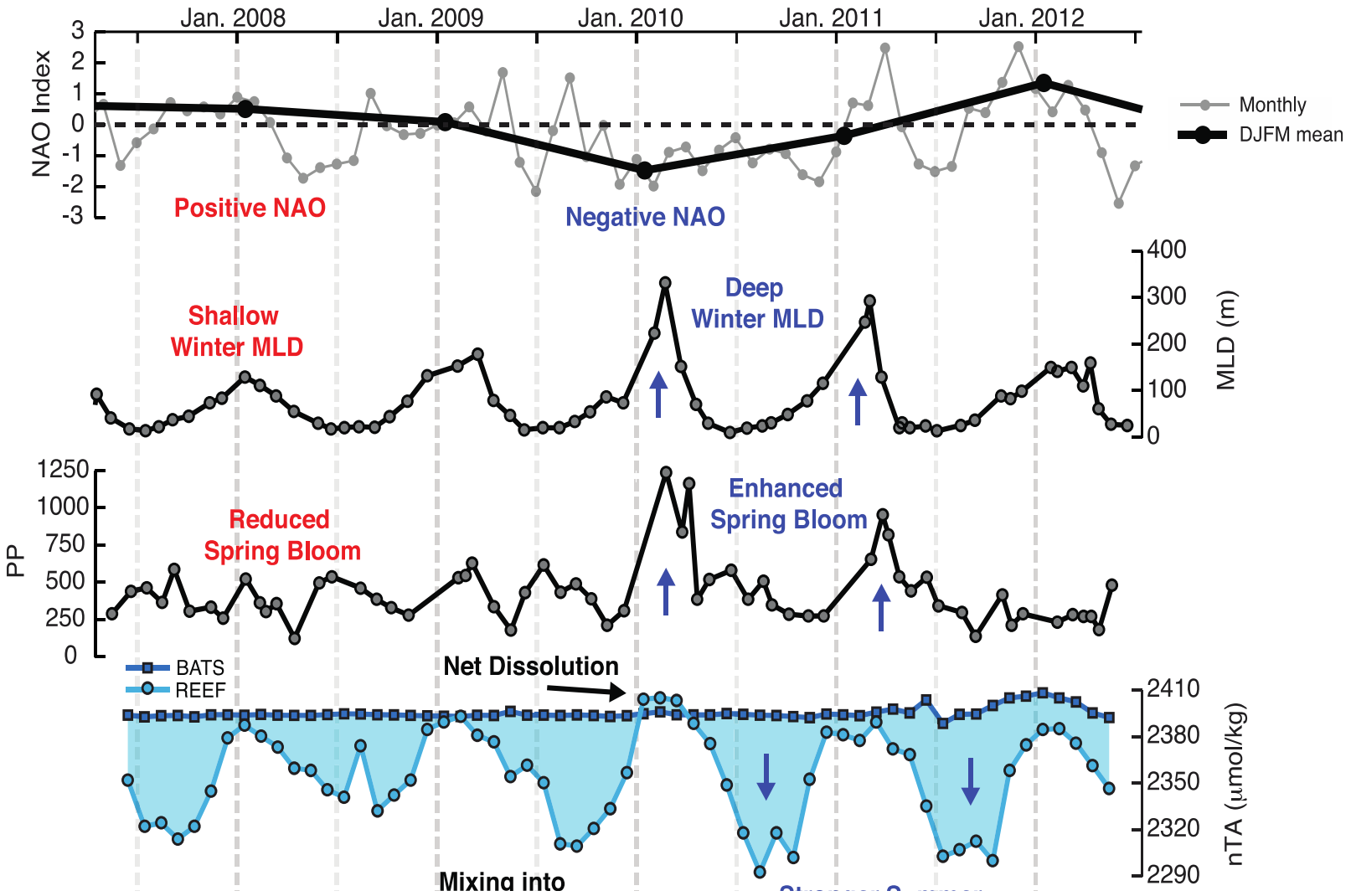

Photo: Yuna Zayasu

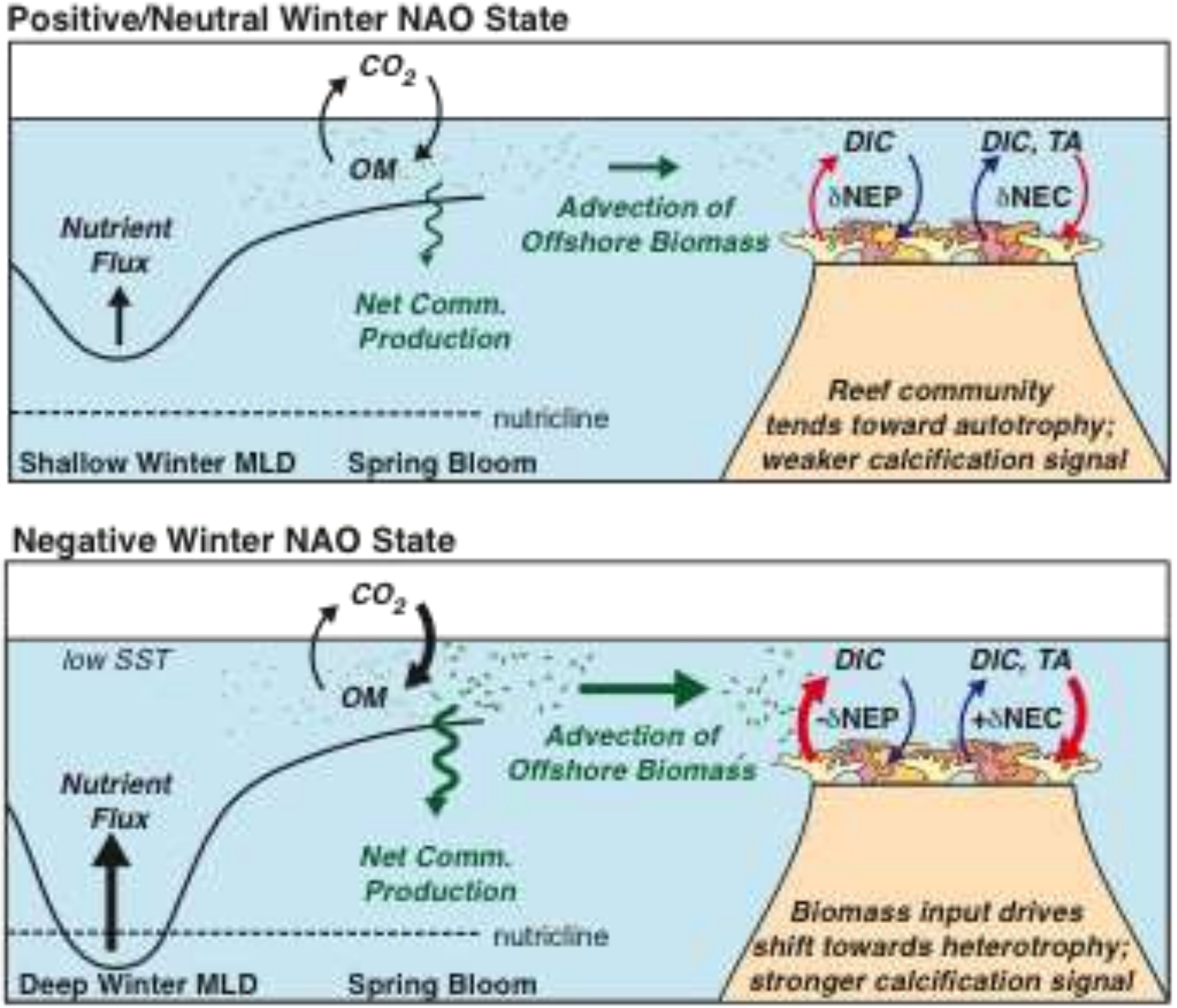


Suzuki & Kawahata 2003

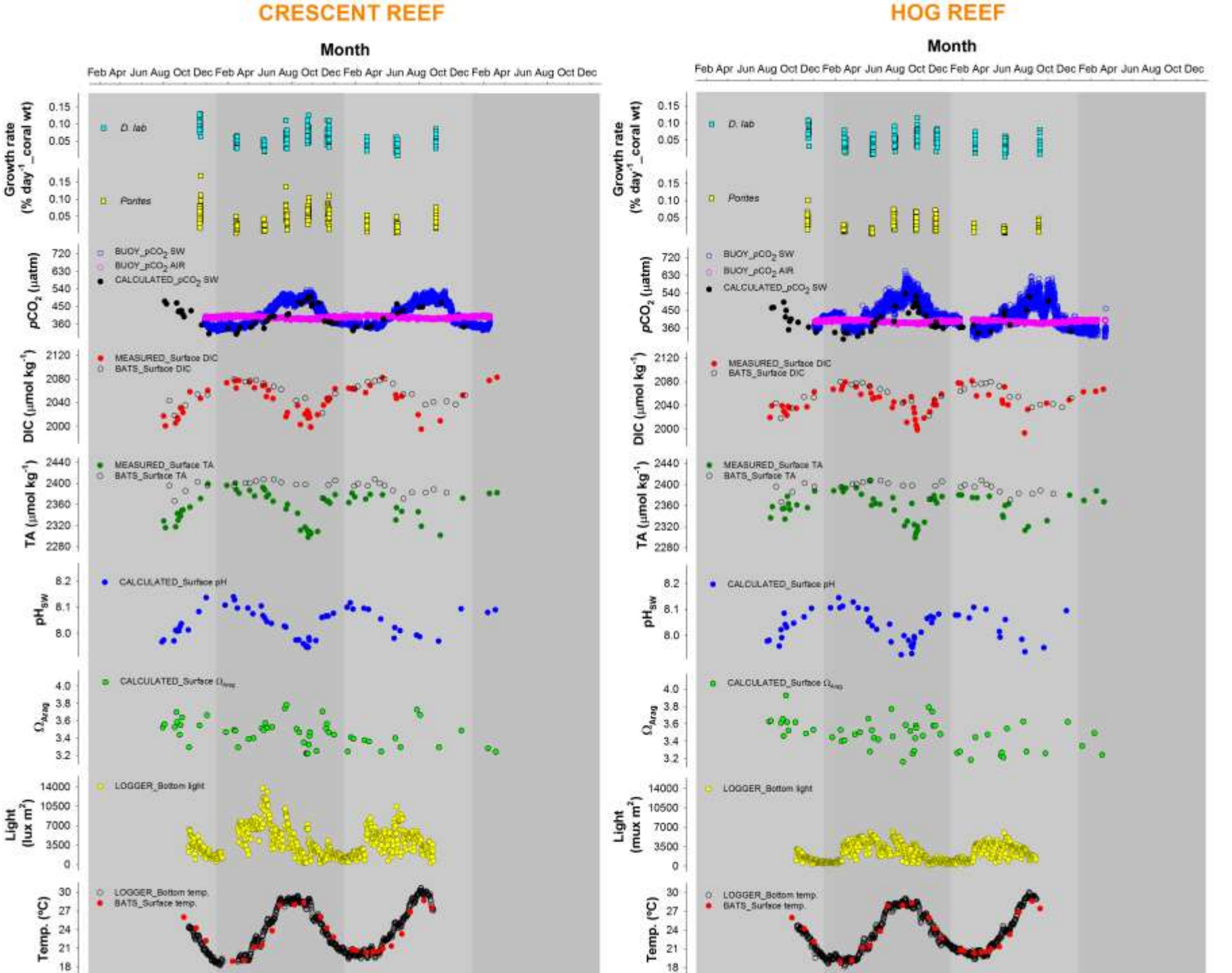

Inshore
Offshore
2400
2300
2200
TA (µmol kg-1)
1900
2000
2100
DIC (µmol kg-1)
8.2
8.0
7.8
7.6
7.4
pH


Map pCO_2 buoy
Coral growth experiment
WQMP
^7Be
BATS
$CaCO_3$ dissolution experiment
Hog reef
NC
Crescent reef
MP
DY
TB
GS
BATS 80km S
CO_2 buoys
Temporal data
Spatial data
Coral calcification
in situ
ex situ
Community calc.
Ecosystem calc.
Bioerosion

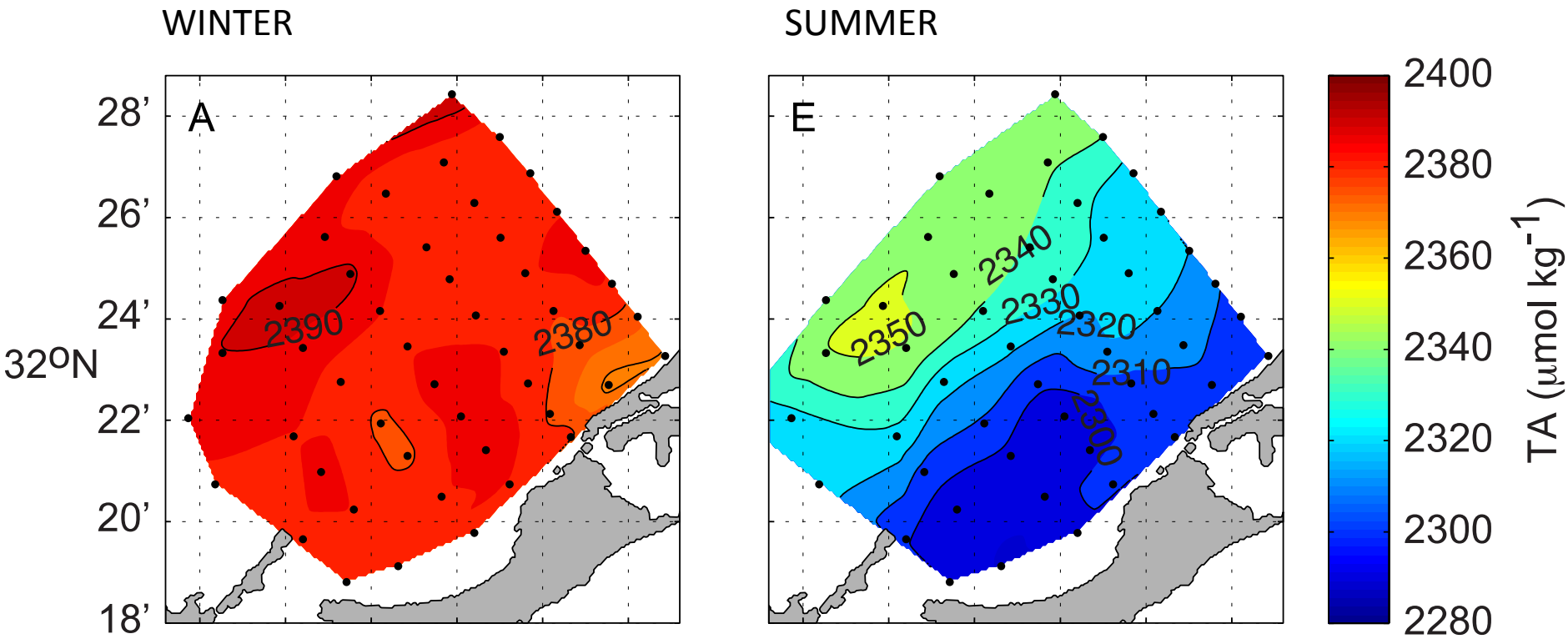

Jan. 2008
Jan. 2009
Jan. 2010
Jan. 2011
Jan. 2012
NAO Index
3
2
1
0
-1
-2
-3
Positive NAO
Negative NAO
Monthly
DJFM mean
Shallow
Winter MLD
Deep
Winter MLD
400
300
200
100
0
MLD (m)
PP
1250
1000
750
500
250
0
Reduced
Spring Bloom
Enhanced
Spring Bloom
BATS
REEF
Net Dissolution
2410
2380
2350
2320
2290
nTA (µmol/kg)
Mixing into



Yeakel et al. *in review*


CRESCENT REEF
HOG REEF
Month
Feb Apr Jun Aug Oct Dec Feb Apr Jun Aug Oct Dec Feb Apr Jun Aug Oct Dec Feb Apr Jun Aug Oct Dec
Growth rate (% day⁻¹_coral wt)
D. labPontes
pCO2 (µatm)
BUOY_pCO2 SW
BUOY_pCO2 AIR
CALCULATED_pCO2 SW
DIC (µmol kg⁻¹)
MEASURED_Surface DIC
BATS_Surface DIC
TA (µmol kg⁻¹)
MEASURED_Surface TA
BATS_Surface TA
pHSW
CALCULATED_Surface pH
ΩArag
CALCULATED_Surface ΩArag
Light (lux m²)
Light (mux m²)
LOGGER_Bottom light
Temp. (°C)
LOGGER_Bottom temp.
BATS_Surface temp.

Spatial trends in Bermuda surface seawater TA



Andersson et al. 2013

What can we do about ocean acidification?

RIO+20
United Nations Conference
on Sustainable Development

166. We call **for support to initiatives that address ocean acidification** and the impacts of climate change on marine and coastal ecosystems and resources. In this regard, we reiterate the **need to work collectively to prevent further ocean acidification, as well as enhance the resilience of marine ecosystems** and of the communities whose livelihoods depend on them, and to **support marine scientific research, monitoring and observation of ocean acidification and particularly vulnerable ecosystems**, including through enhanced international cooperation in this regard.

Rio+20 outcome document: The future we want

Draft outcome document of the third International Conference on Small Island Developing States

- **Ocean Acidification: item 32, 58e, 58n, 63f**

- **58e:** Undertake urgent action to protect coral reefs and other vulnerable marine ecosystems through the development and implementation of comprehensive and integrated approaches for the management and the enhancement of their resilience to withstand pressures, including from ocean acidification and invasive species, and by drawing on measures such as those identified in the International Coral Reef Initiative Framework for Action 2013.

- **58n:** Enhance local, national, regional and global cooperation to tackle the causes of ocean acidification and to further study and minimize its impacts, including through information sharing, regional workshops, integrating SIDS scientists into international research teams, taking steps to make marine ecosystems more resilient to the impacts of ocean acidification and through the possible development of a SIDS wide strategy on ocean acidification.

- **63f:** Enhance SIDS agriculture and fisheries' resilience to the adverse impacts of climate change, ocean acidification and natural disasters.