Lophelia II: Coral Distribution & Ocean Chemistry

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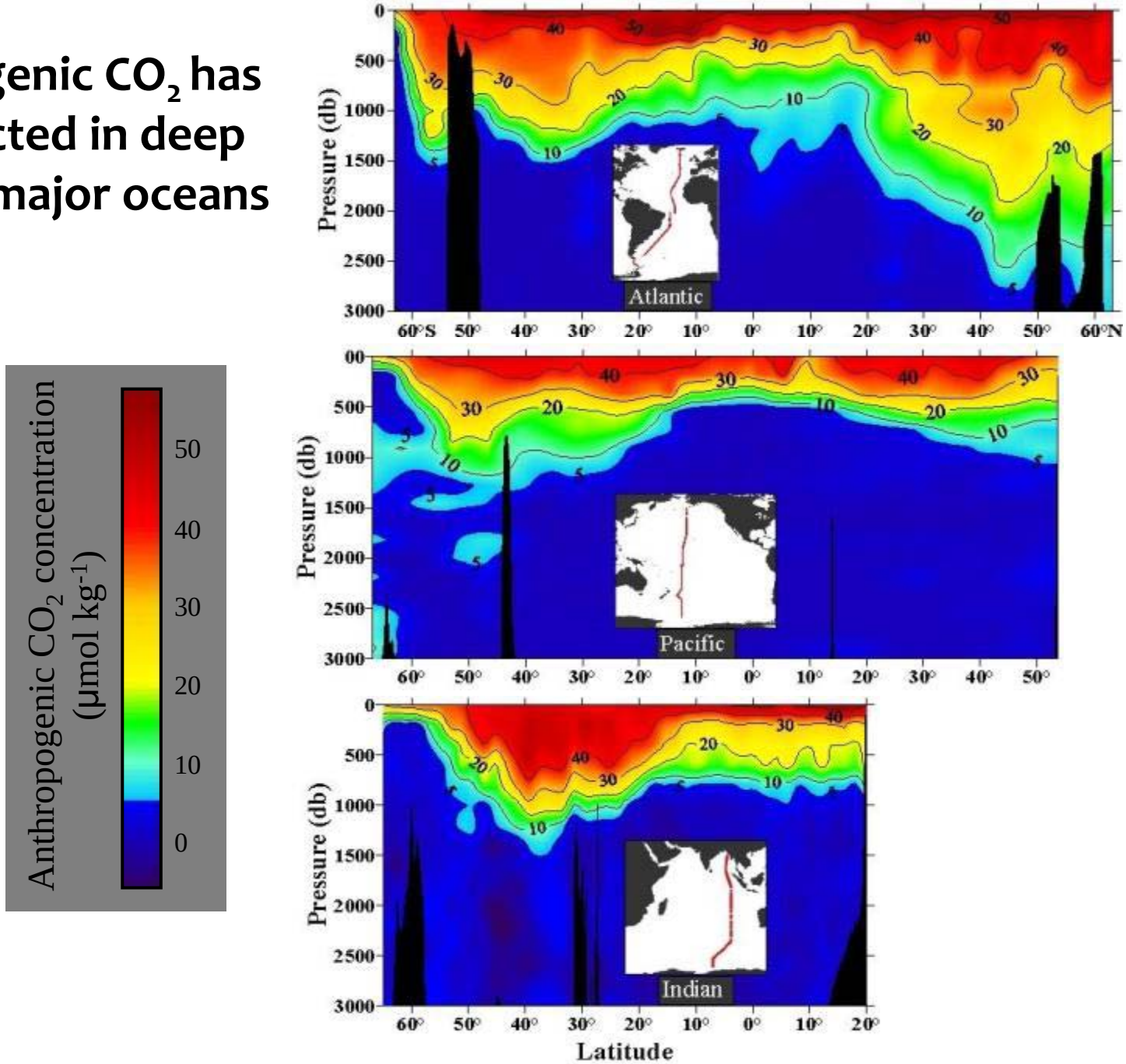
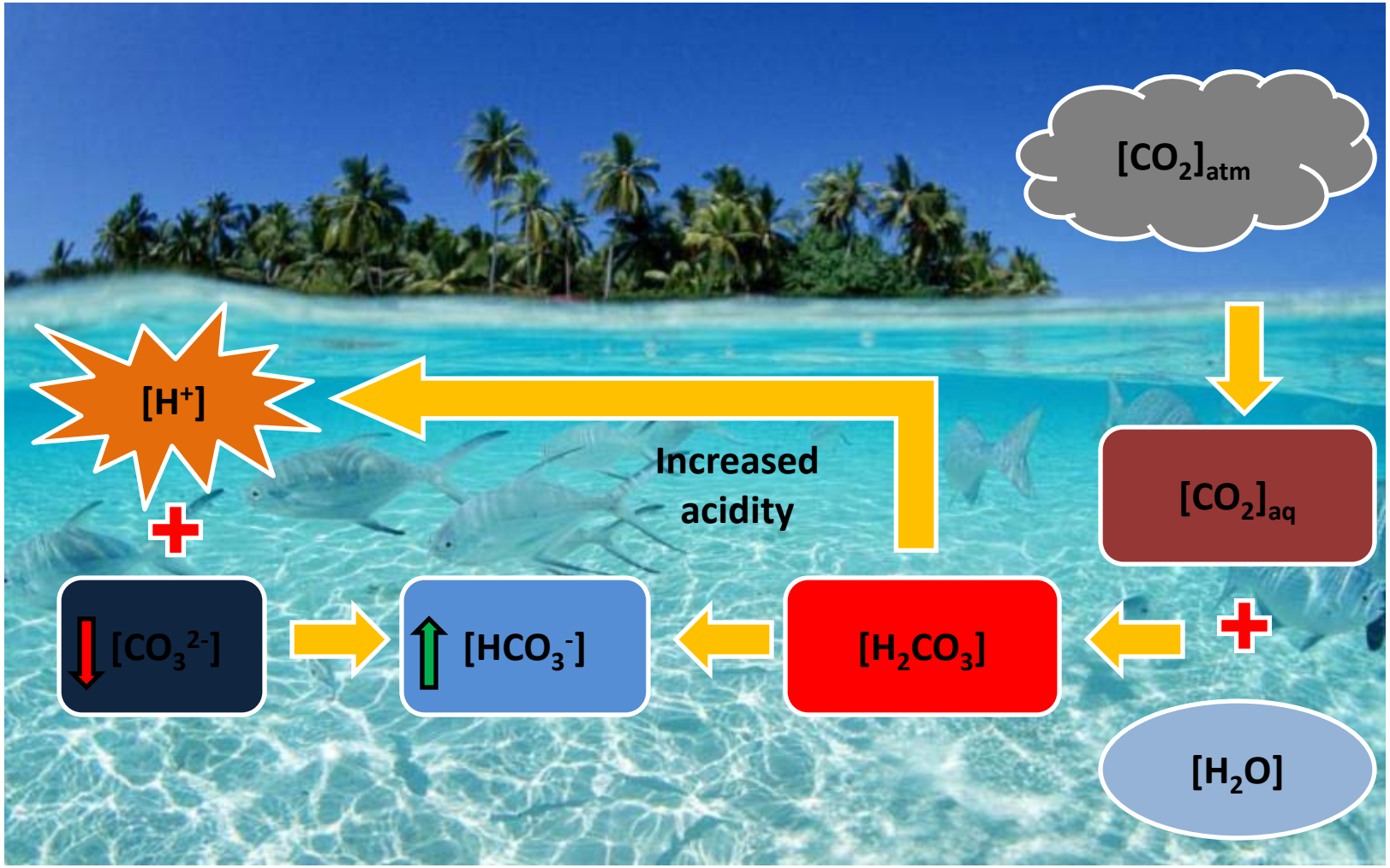
Anthropogenic CO_2 has been detected in deep waters of major oceans

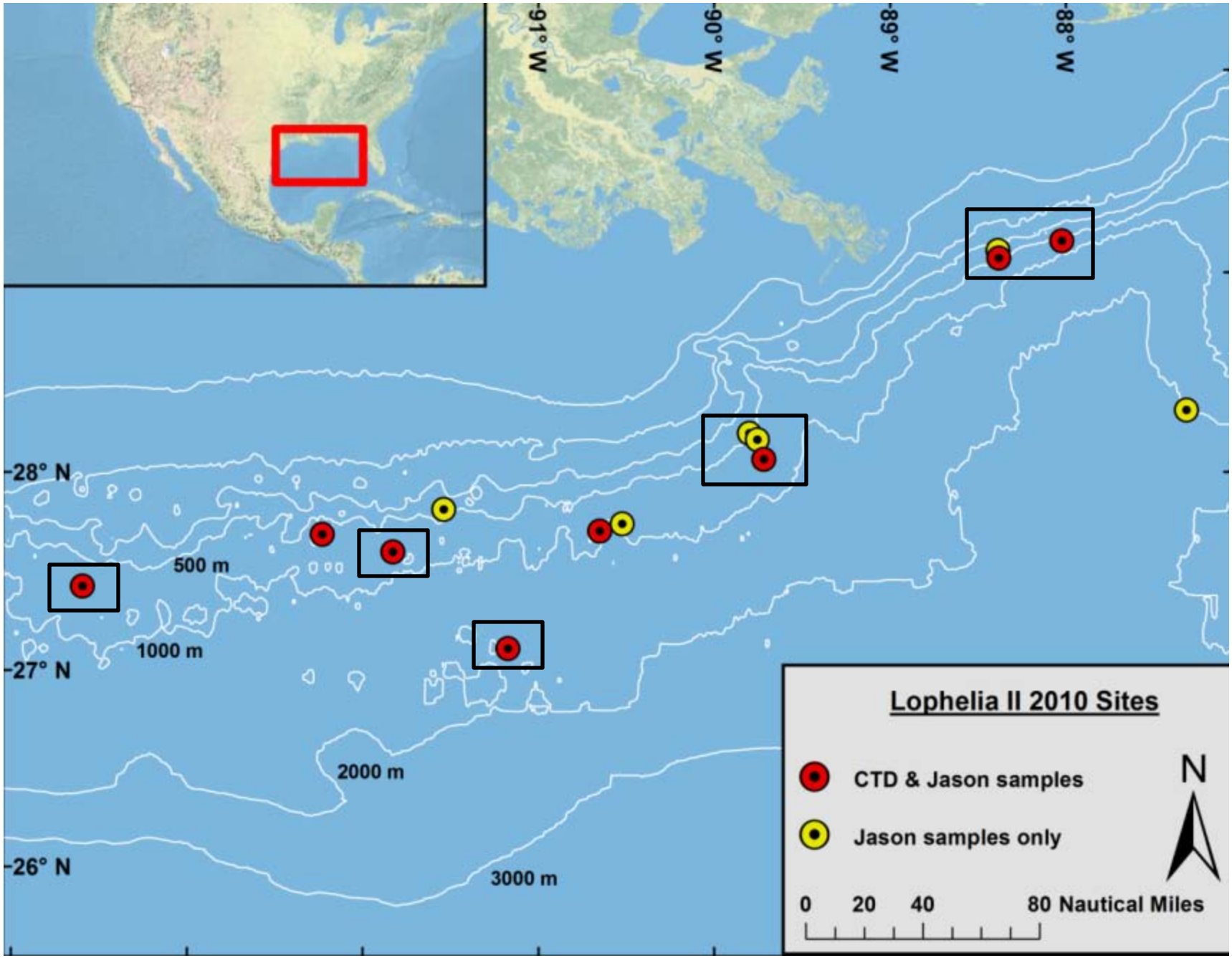


Sabine et al. 2004

Ocean chemistry is heavily influenced by interactions with atmospheric CO_2



Consumption of CO_3^{2-} by excess H^+ lowers the aragonite saturation state (Ω_{arag})


-91° W
-90° W
-89° W
-88° W
-28° N
-27° N
-26° N
500 m
1000 m
2000 m
3000 m
Lophelia II 2010 Sites
CTD & Jason samples
Jason samples only
N
0 20 40 80 Nautical Miles

Sample collection:

- 7 Niskin (1.7 L) rack on *Jason*
  (courtesy I. MacDonald, FSU)
- CTD rosette w/ 12 niskins (2.5 L)
- 14 sites from Oct-Nov 2010 (300–2,500m)
- 150 samples from 8 CTD casts
  & 14 Jason dives

Sample analyses:

Total alkalinity: buffering capacity of seawater;
-Titration with strong acid and CRMs

$$TA = [HCO_3^-] + 2[CO_3^{2-}] + [B(OH)_4^-] + [OH^-] - [H^+]$$

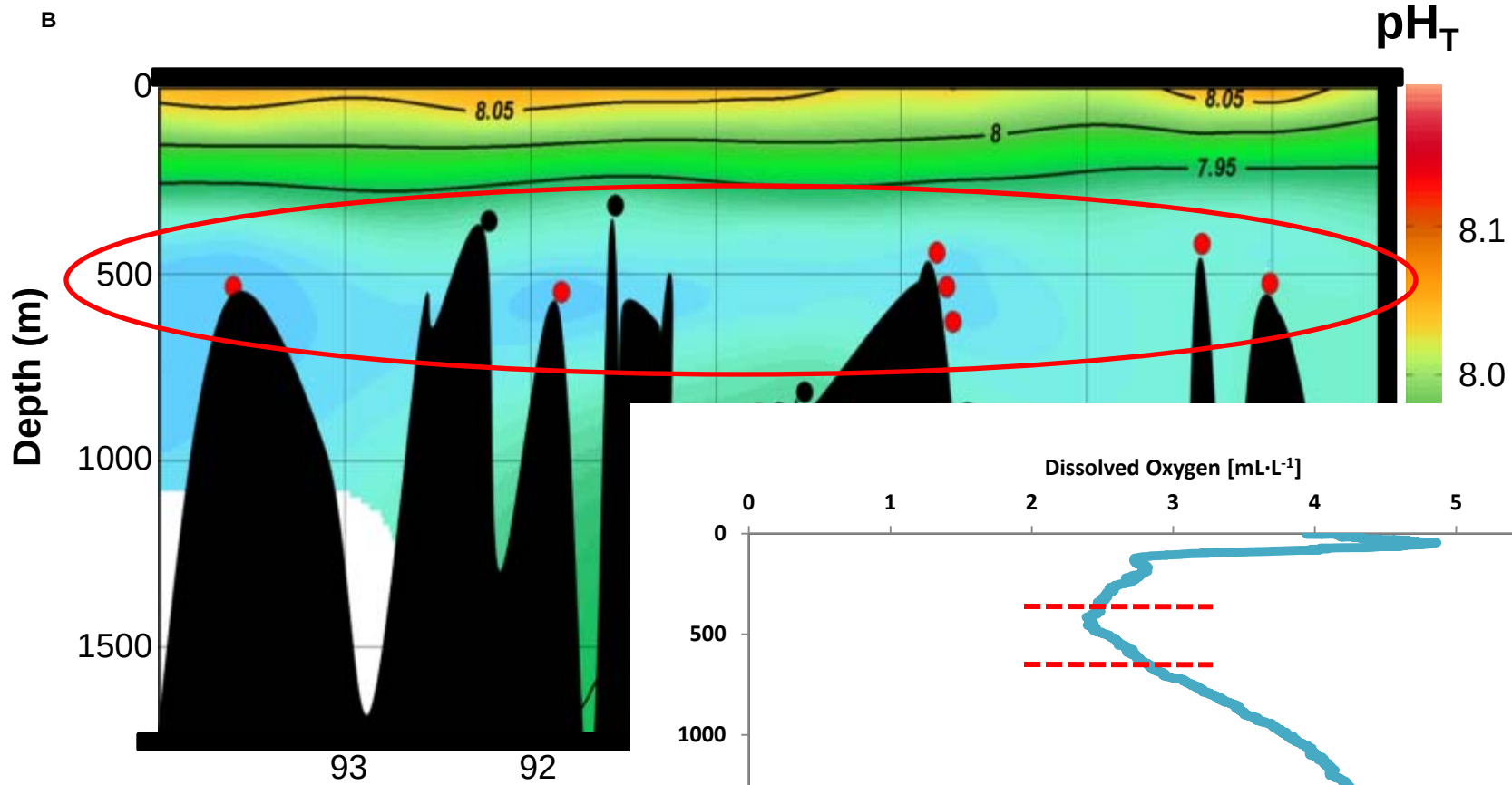
pH_T: concentration of $[H^+]_T$ in SW
-potentiometric measurement with seawater buffers

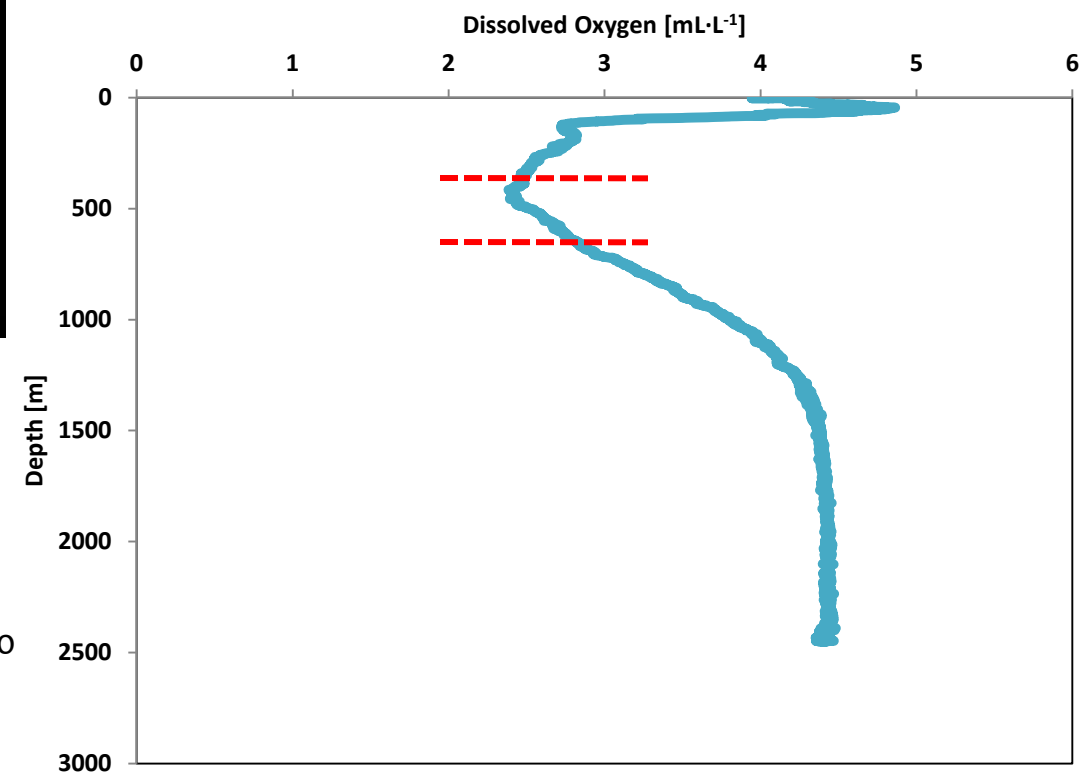
$$[H^+]_T = [H^+]_F + [HSO_4^-]$$

$\Omega_{aragonite}$: calculated with CO2SYS with T, S, P from CTD

$$\Omega_{aragonite} = \frac{[Ca^{2+}][CO_3^{2-}]}{K'_{sp}}$$

Scleractinians ● present ● absent



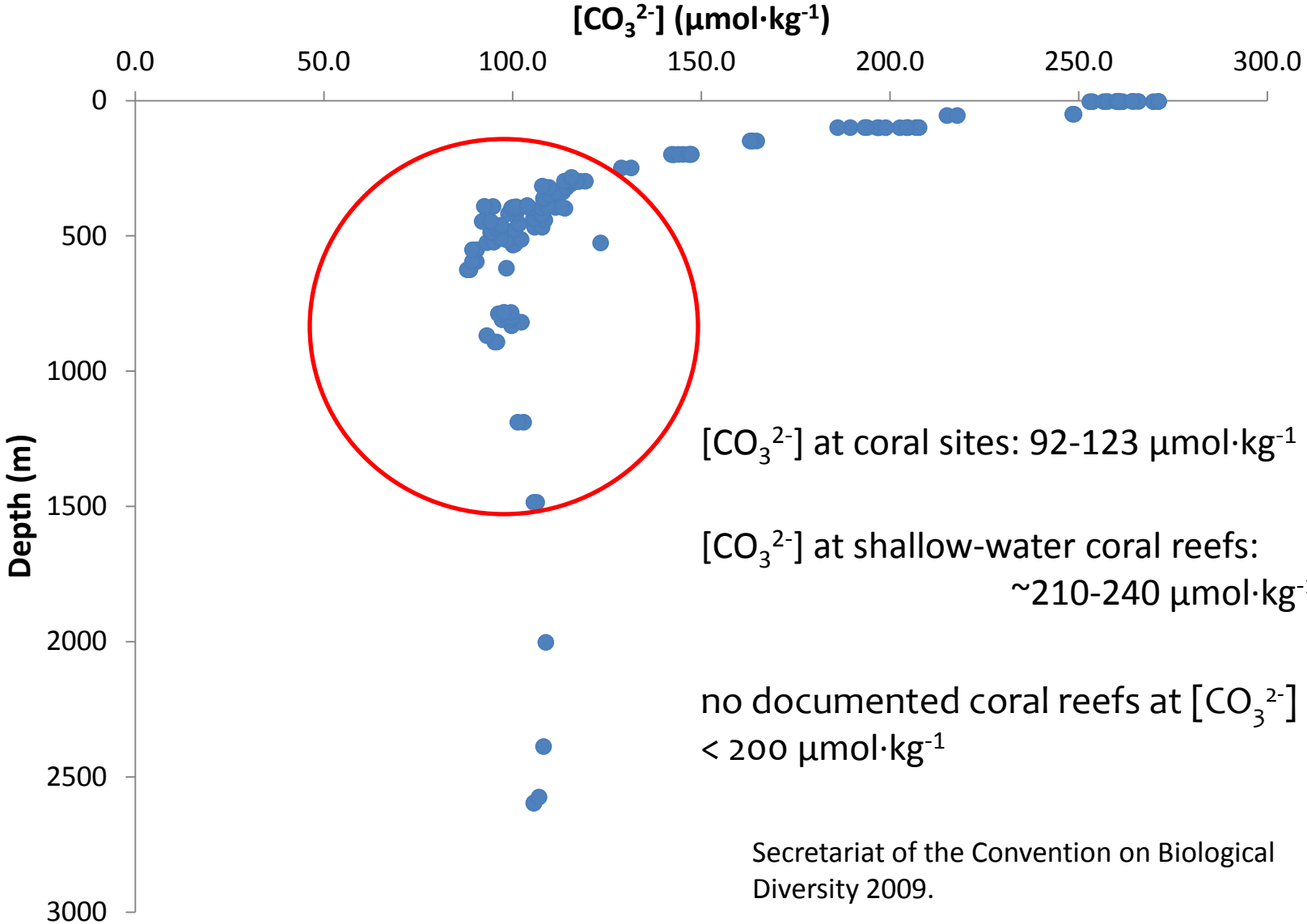


Average surface pH$_T$ for GoM: 8.11

Preindustrial pH for global surface ocean: 8.20

Lowest pH$_T$ at 300–600 m (7.85–8.02)

Scleractinians ● present ● absent

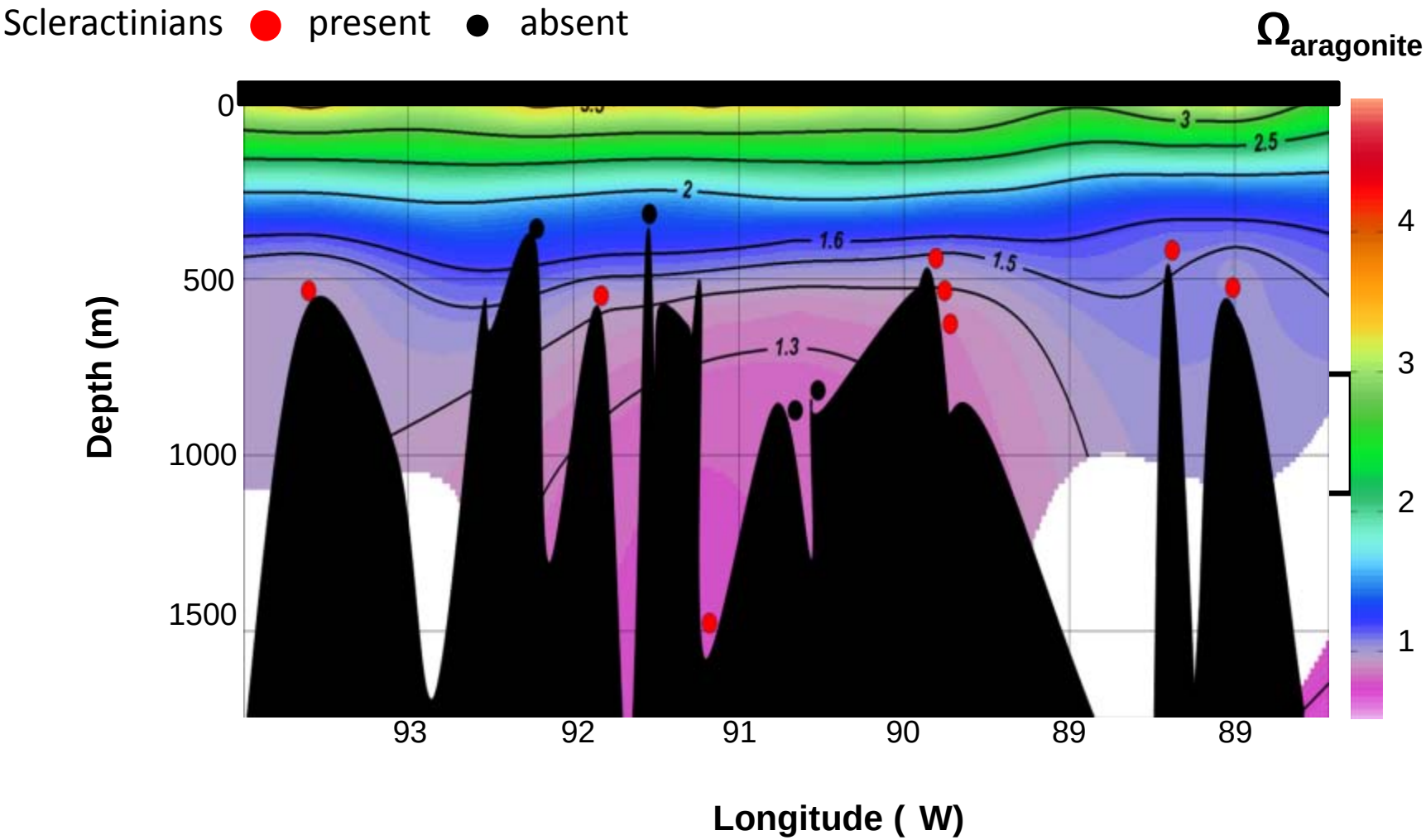


$[CO_3^{2-}]$ at coral sites: 92-123 µmol·kg^{-1}

$[CO_3^{2-}]$ at shallow-water coral reefs: ~210-240 µmol·kg^{-1}

no documented coral reefs at $[CO_3^{2-}]$ < 200 µmol·kg^{-1}

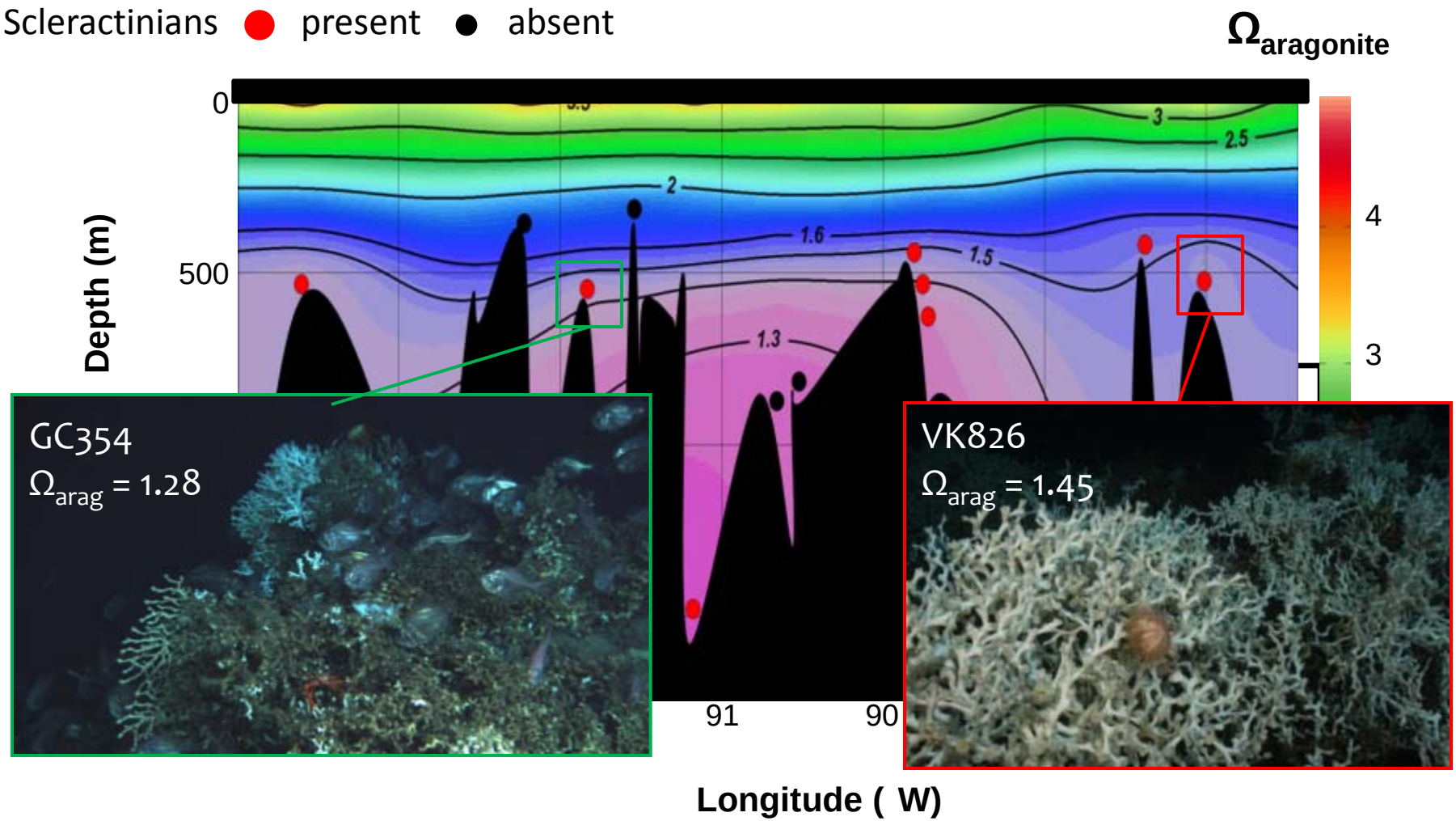
Secretariat of the Convention on Biological Diversity 2009.



$\Omega_{aragonite}$ at coral sites: 1.28-1.69

scleractinian coral reefs at lowest Ω_{arag} yet published

Manzello (2010) reports minimum Ω_{arag} ~ 1.54 at Galapagos coral reefs



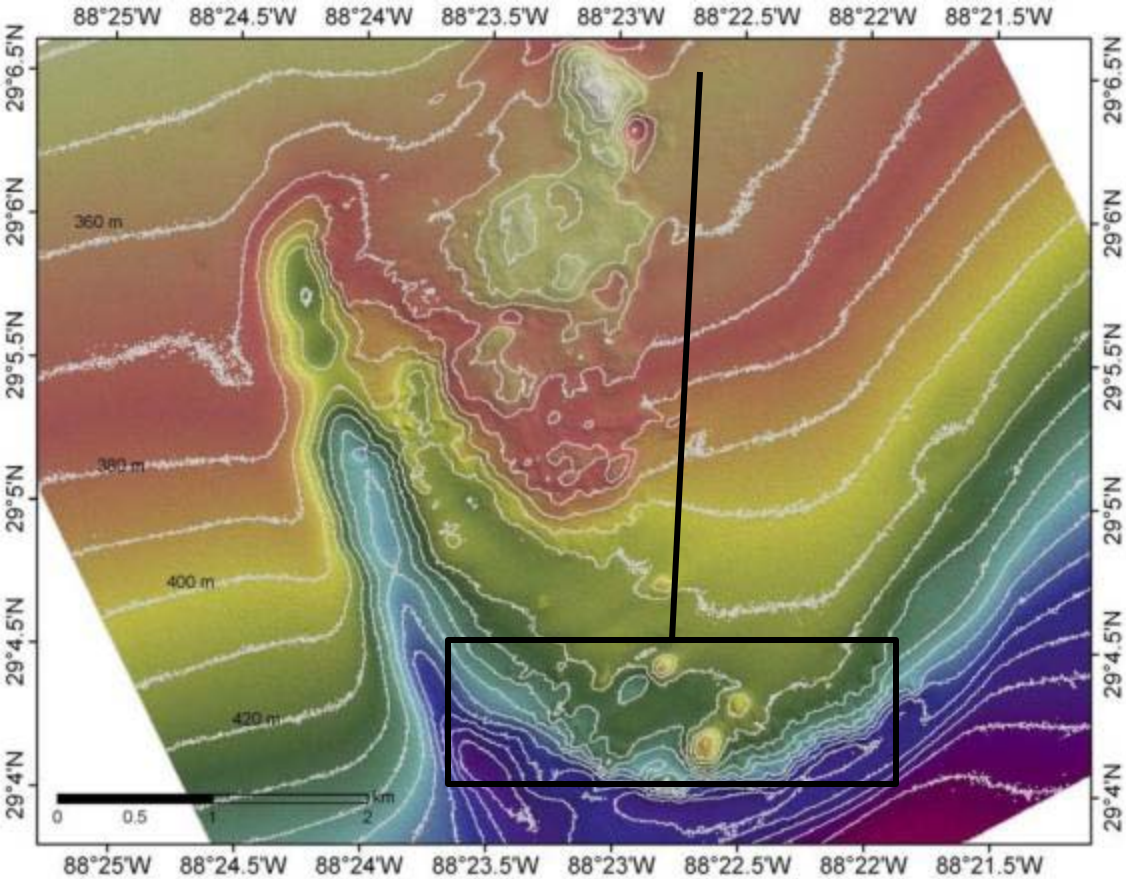
$\Omega_{aragonite}$ at coral sites: 1.28-1.69

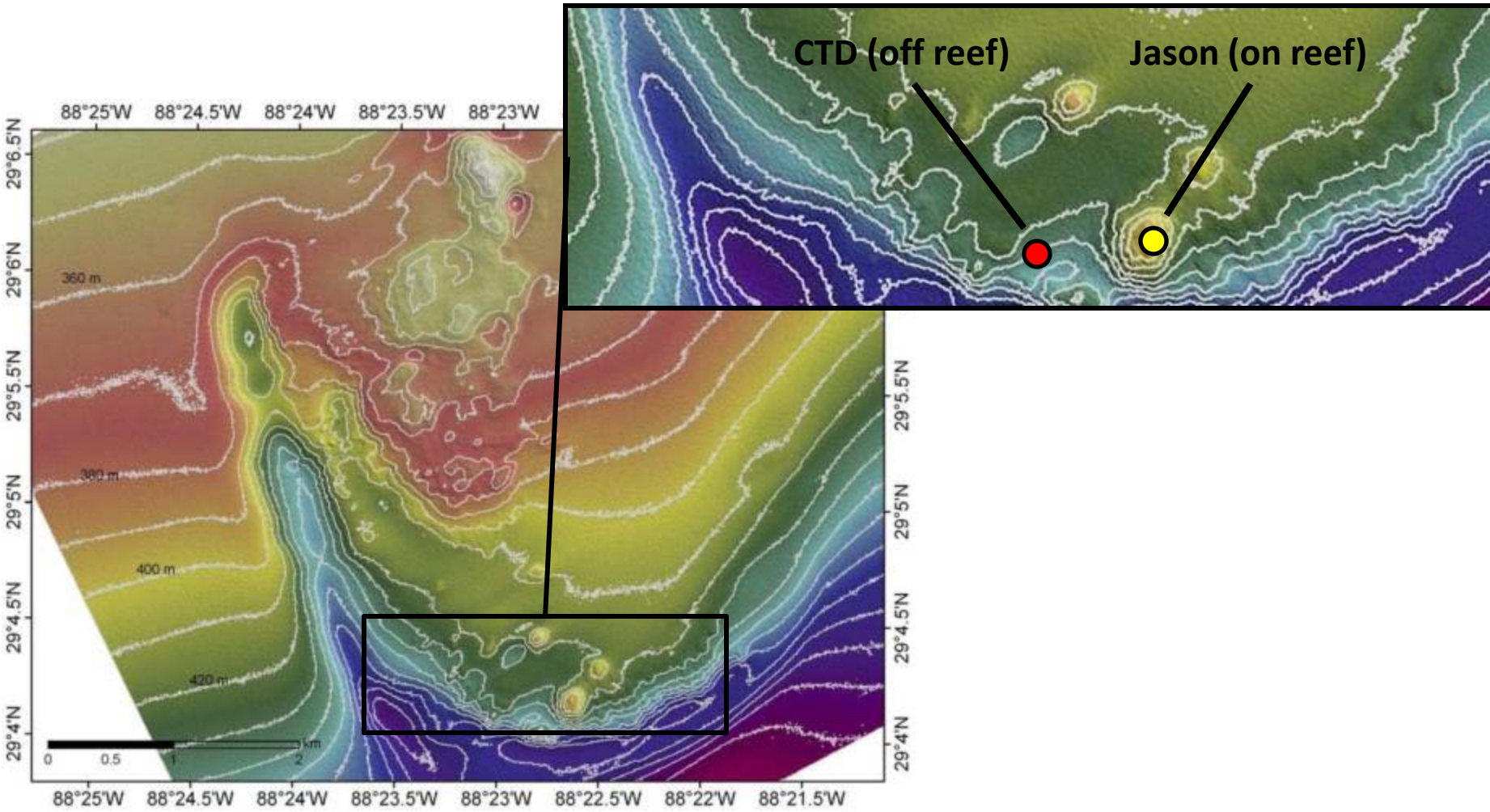
scleractinian coral reefs at lowest Ω_{arag} yet published

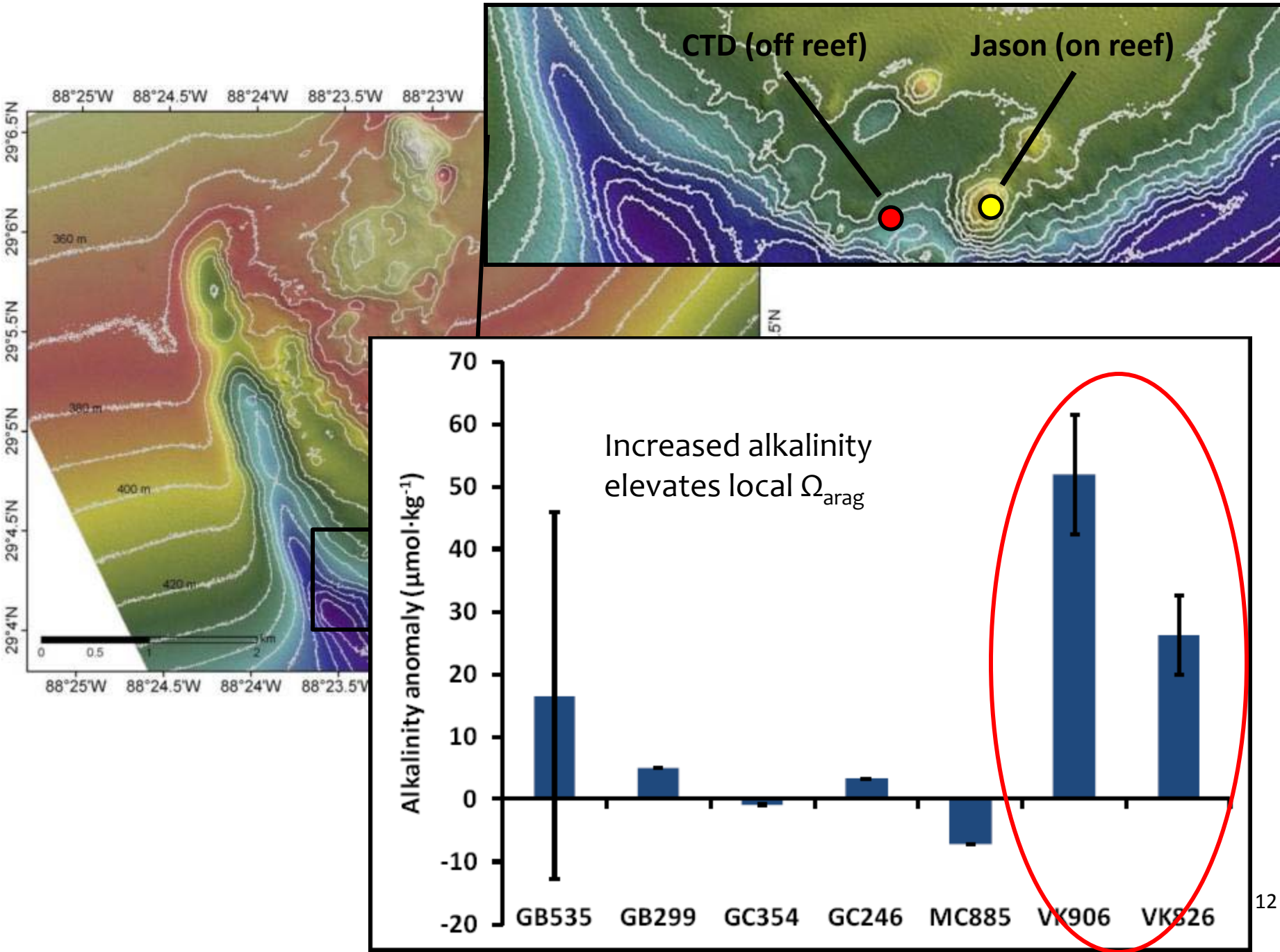
Undersaturation of aragonite detected at ~2,500 m
→ More water samples required to characterize this

Manzello (2010) reports minimum Ω_{arag} ~ 1.54 at Galapagos coral reefs

Alkalinity anomalies at dense coral sites




CTD (off reef)
Jason (on reef)
88°25'W
88°24.5'W
88°24'W
88°23.5'W
88°23'W
88°22.5'W
88°22'W
88°21.5'W
29°6.5'N
29°6'N
29°5.5'N
29°5'N
29°4.5'N
29°4'N
360 m
380 m
400 m
420 m
0
0.5
1
2
km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88°25'W
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88°23'W
29°6.5'N
29°6'N
29°5.5'N
29°5'N
29°4.5'N
29°4'N
360 m
380 m
400 m
420 m
0
0.5
1
2
km
Increased alkalinity elevates local Ω_{arag}
Alkalinity anomaly (µmol·kg^{-1})
70
60
50
40
30
20
10
0
-10
-20
GB535
GB299
GC354
GC246
MC885
VK906
VK826

Live *Lophelia* experiments

Facilities:

- New maintenance aquarium w/ chiller

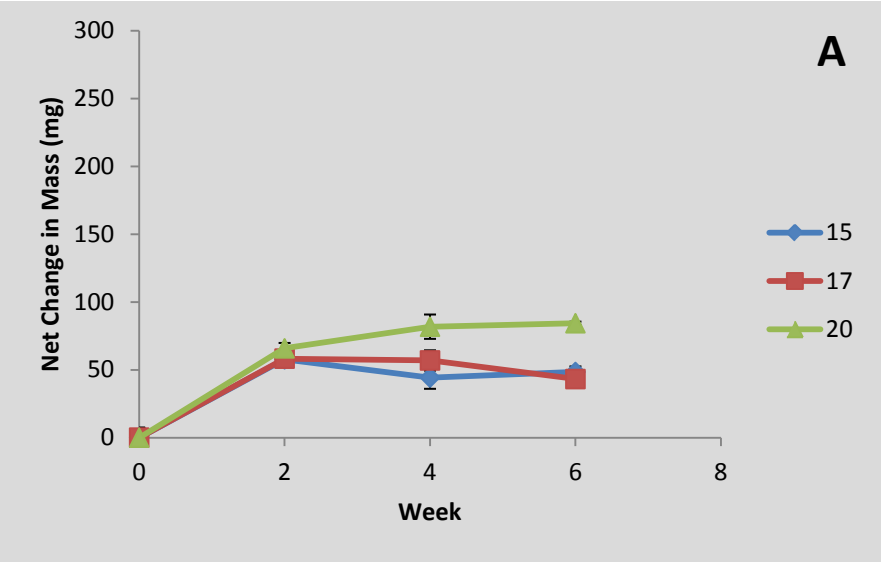
- New controller for cold-room
  no malfunctions since installation

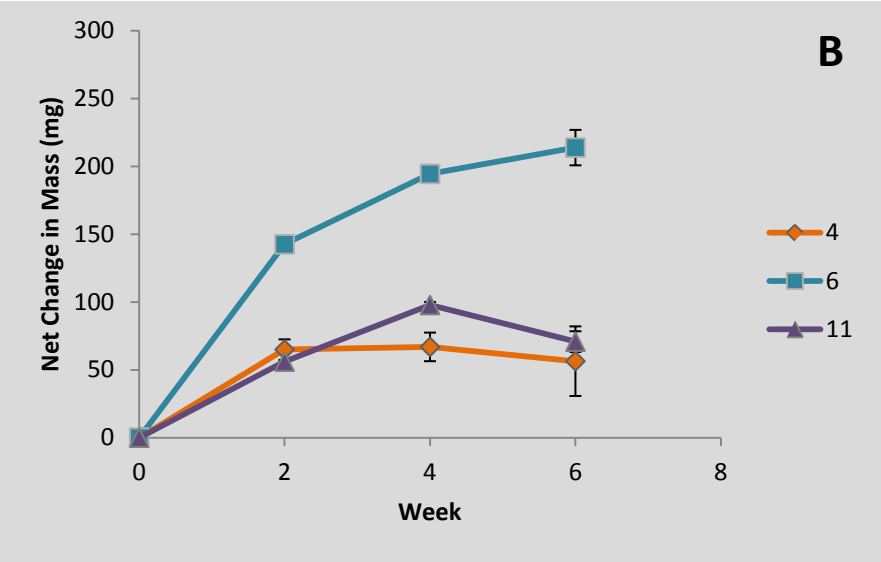
Samples:

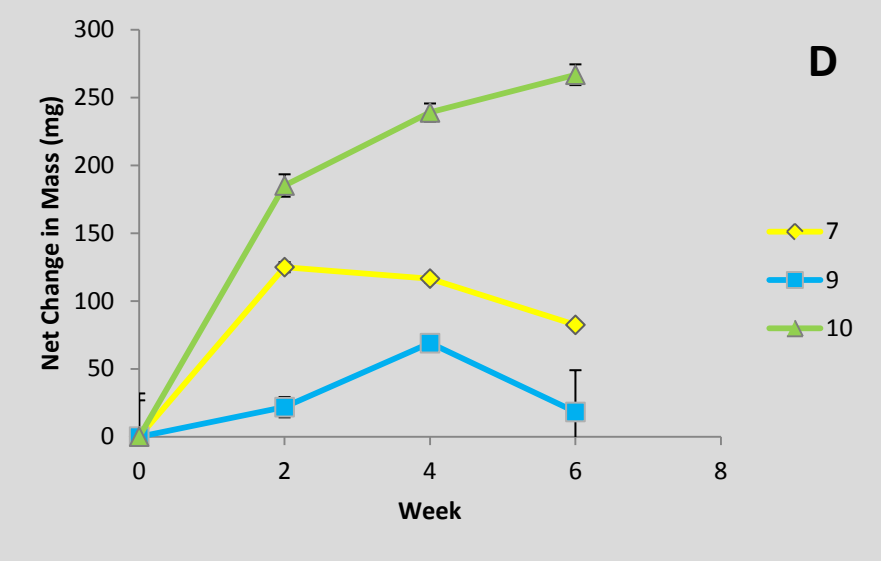
- New collections from 2010 cruise

Seawater manipulations:

- Instant Ocean vs. synthetic seawater







pH = 7.90
TA = 2400 μmol·kg^{-1}
Ω_{arag} = 1.60

Most growth observed in first 2 weeks

New direction with seawater manipulations:

acidified IO + bubbling with O_2

More data coming this summer

Future Questions & Directions

1. **Is the deep GoM showing effects of ongoing ocean acidification?**

   → estimated Ω_{arag} at CWC sites = 2.0 prior to Industrial Revolution (Guinotte et al. 2006)

2. **What is the controlling factor in coral calcification?**

   Ω_{arag}? $[CO_3^{2-}]$? $[HCO_3^-]$?

3. **How does *L. pertusa* sustain reef development under low aragonite saturation? Is it a potential model organism for studies of coral persistence in the presence of ongoing ocean acidification?**

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Dickson Lab, Scripps

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- NOAA
- Temple University

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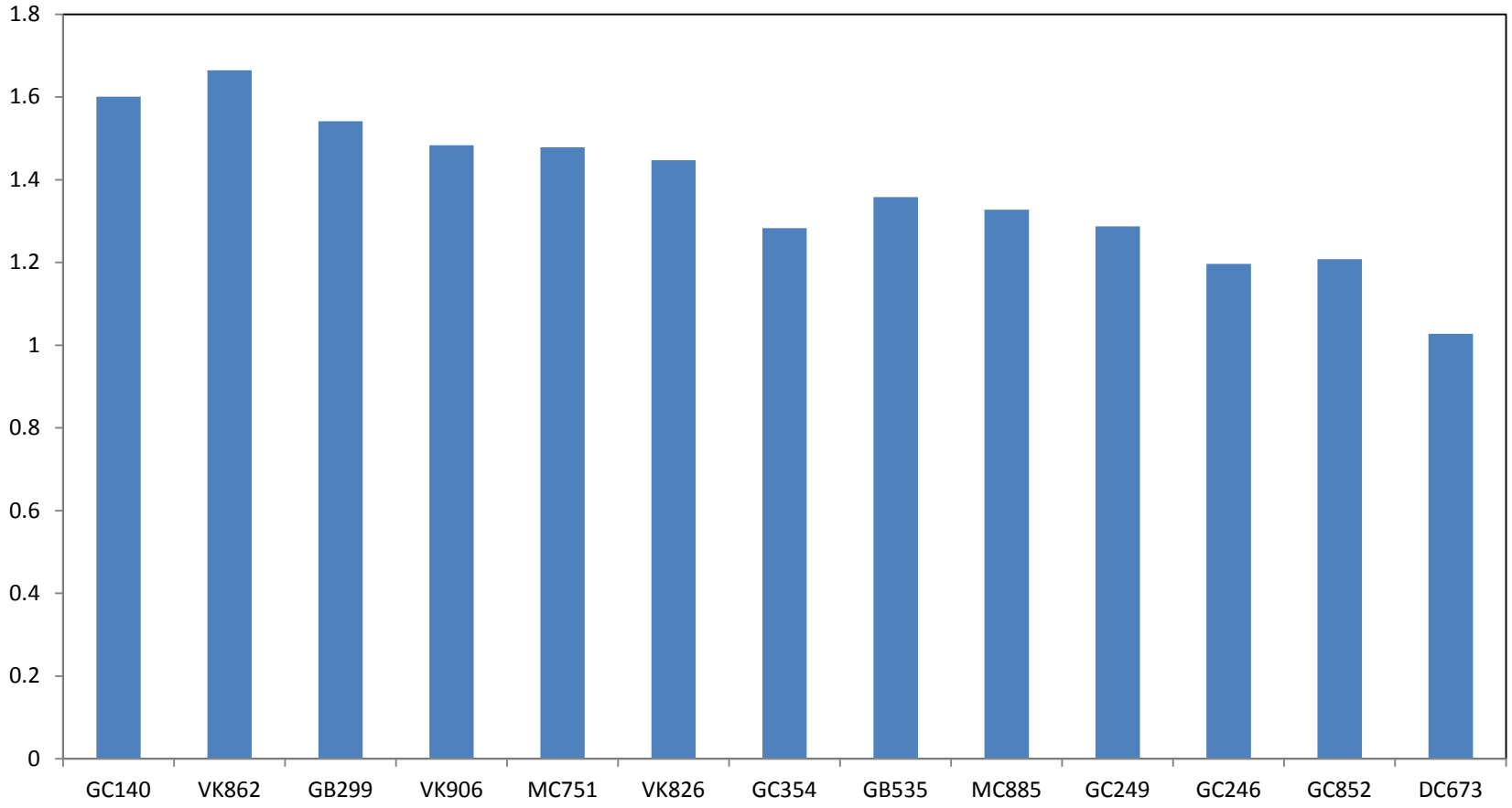
- SICB Grant-in-aid of Research

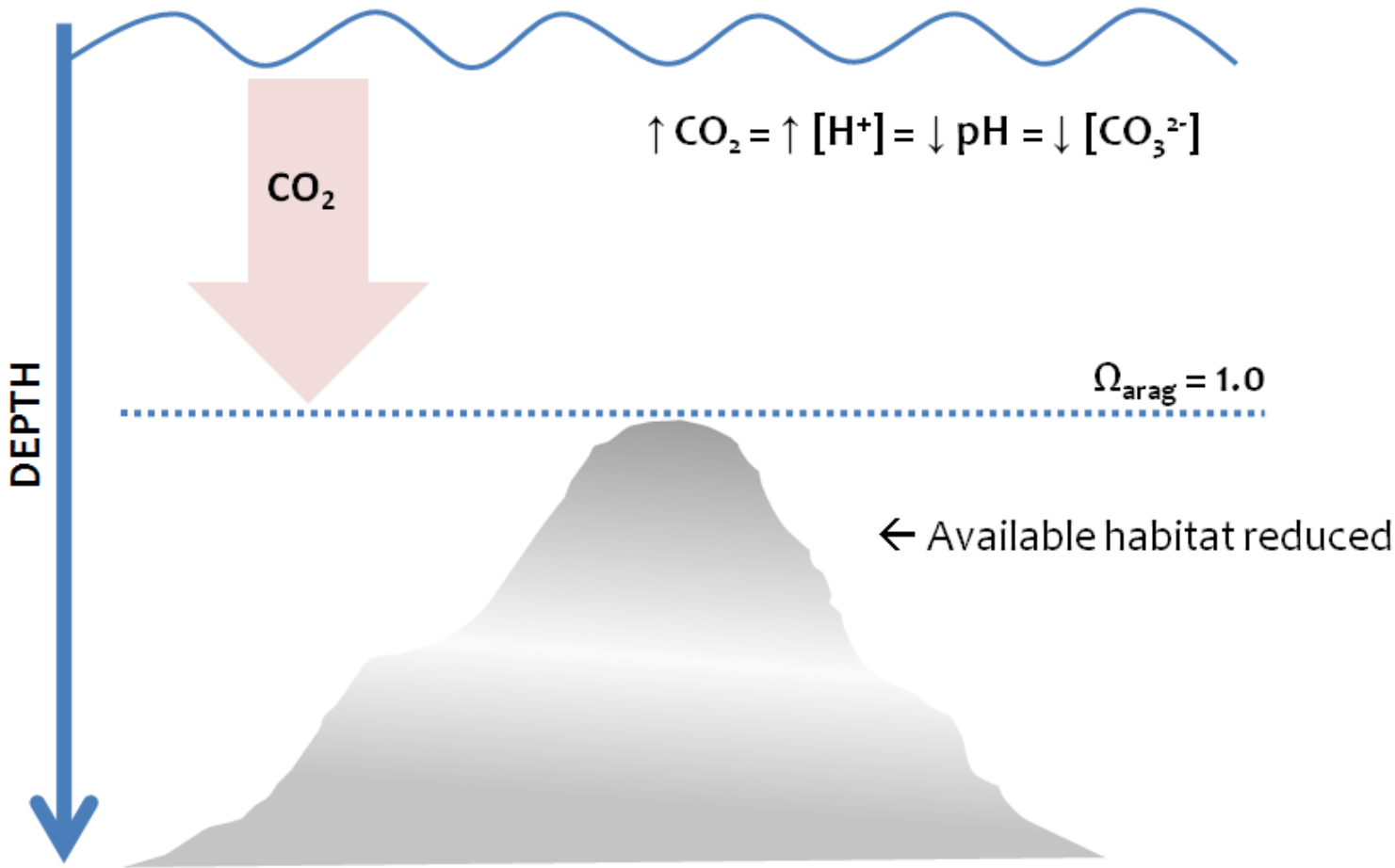
Seafloor images courtesy of *Lophelia II* team


1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
GC140
VK862
GB299
VK906
MC751
VK826
GC354
GB535
MC885
GC249
GC246
GC852
DC673

Increasing Atmospheric CO_2 and the Aragonite Saturation Horizon

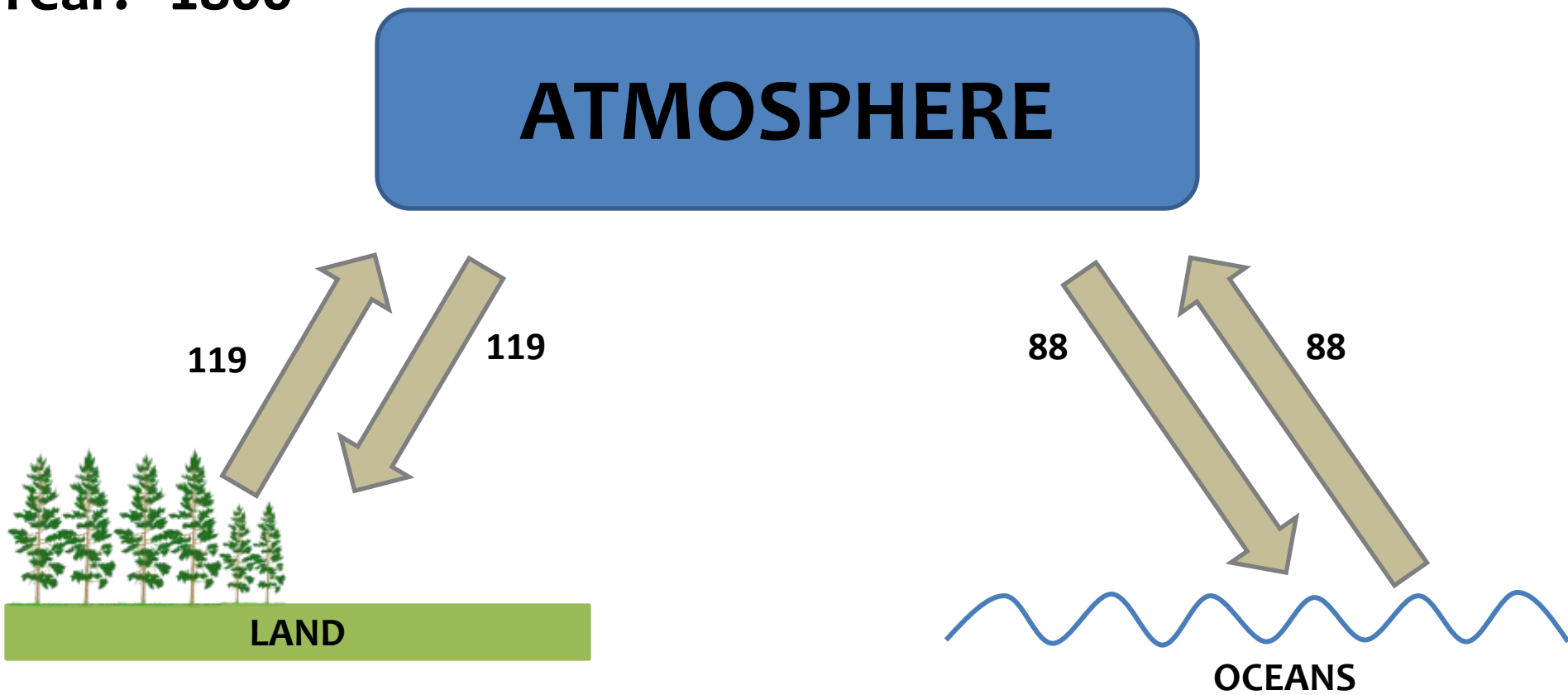
uptake of atmospheric CO_2 lowers oceanic pH

with lower pH, the $[CO_3^{2-}]$ declines and the ASH shoals



Ocean chemistry is tightly linked to the Global Carbon Cycle

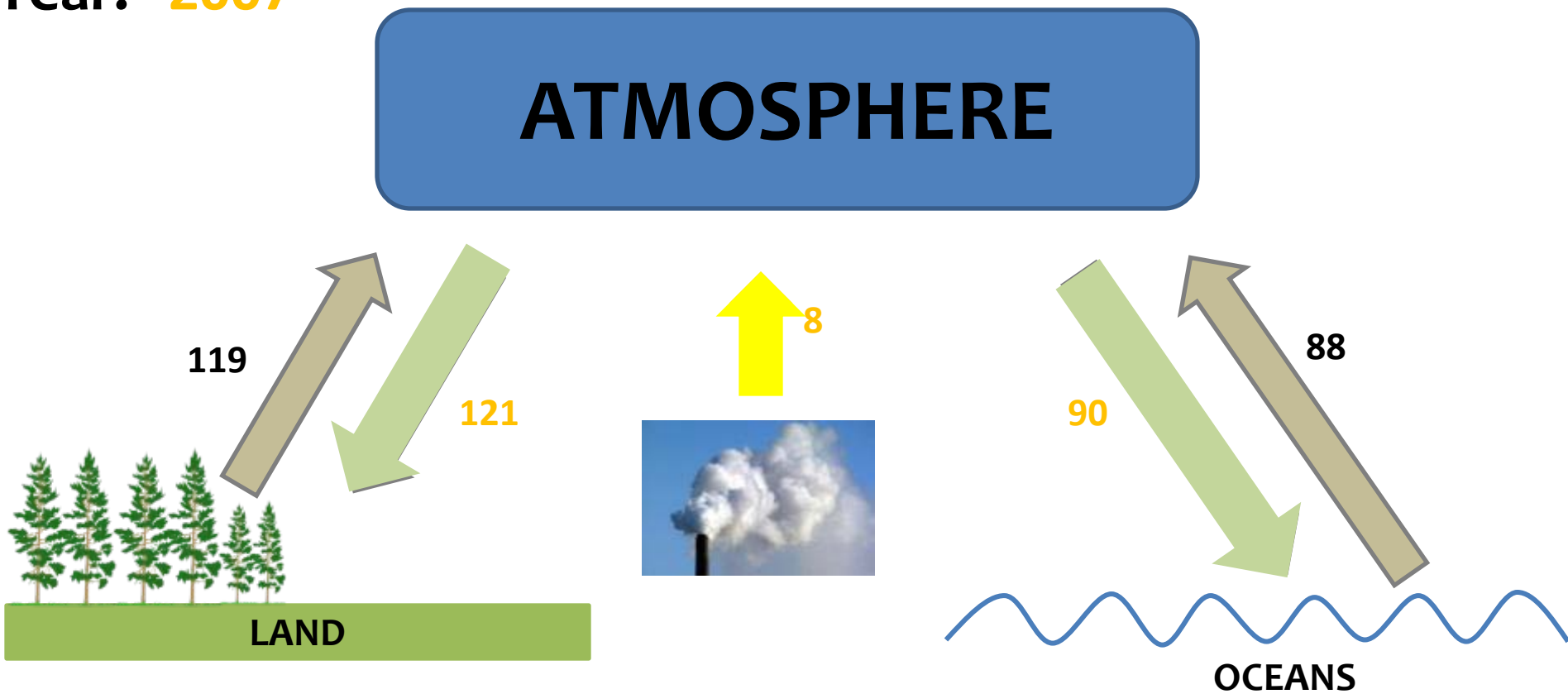
Year: 1800



JP Barry

Ocean chemistry is tightly linked to the Global Carbon Cycle

Year: 2007



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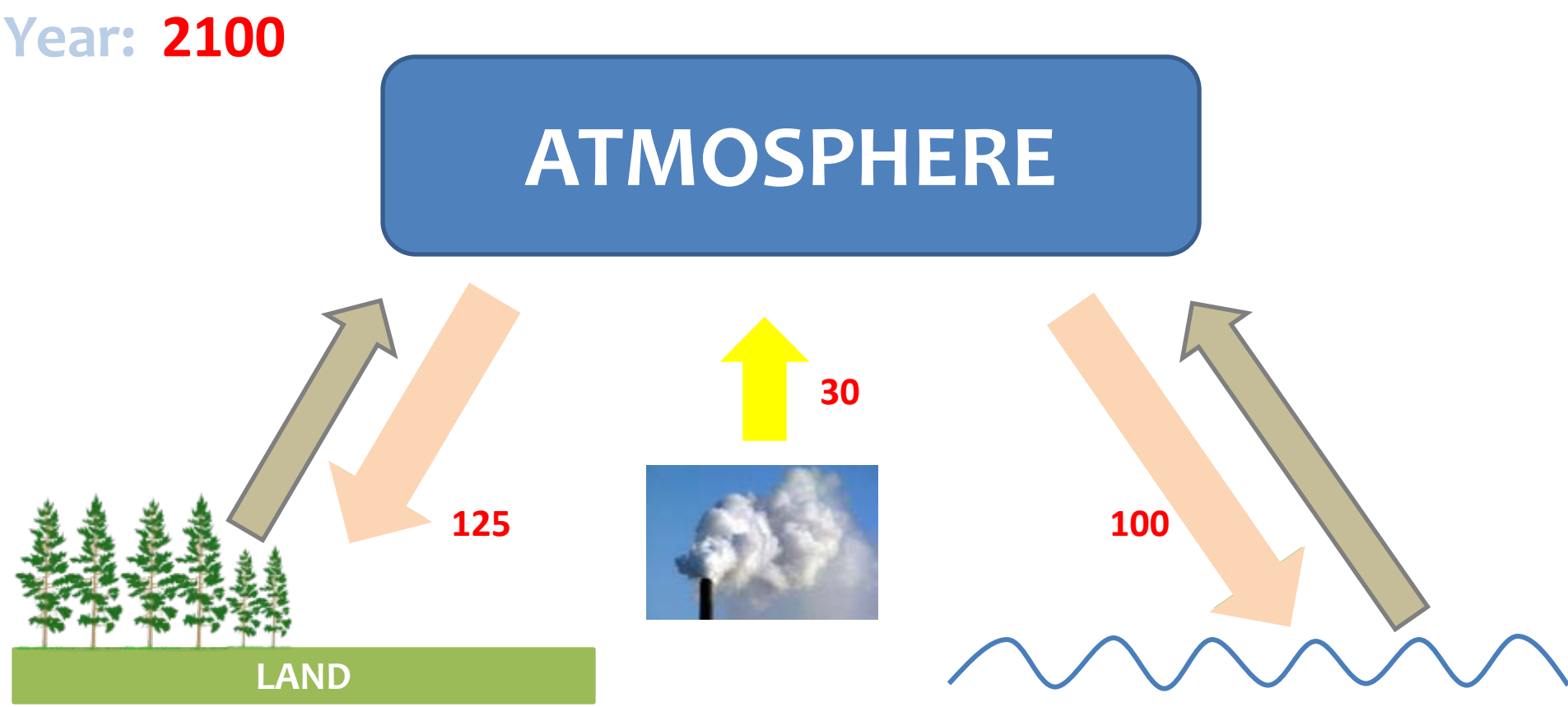

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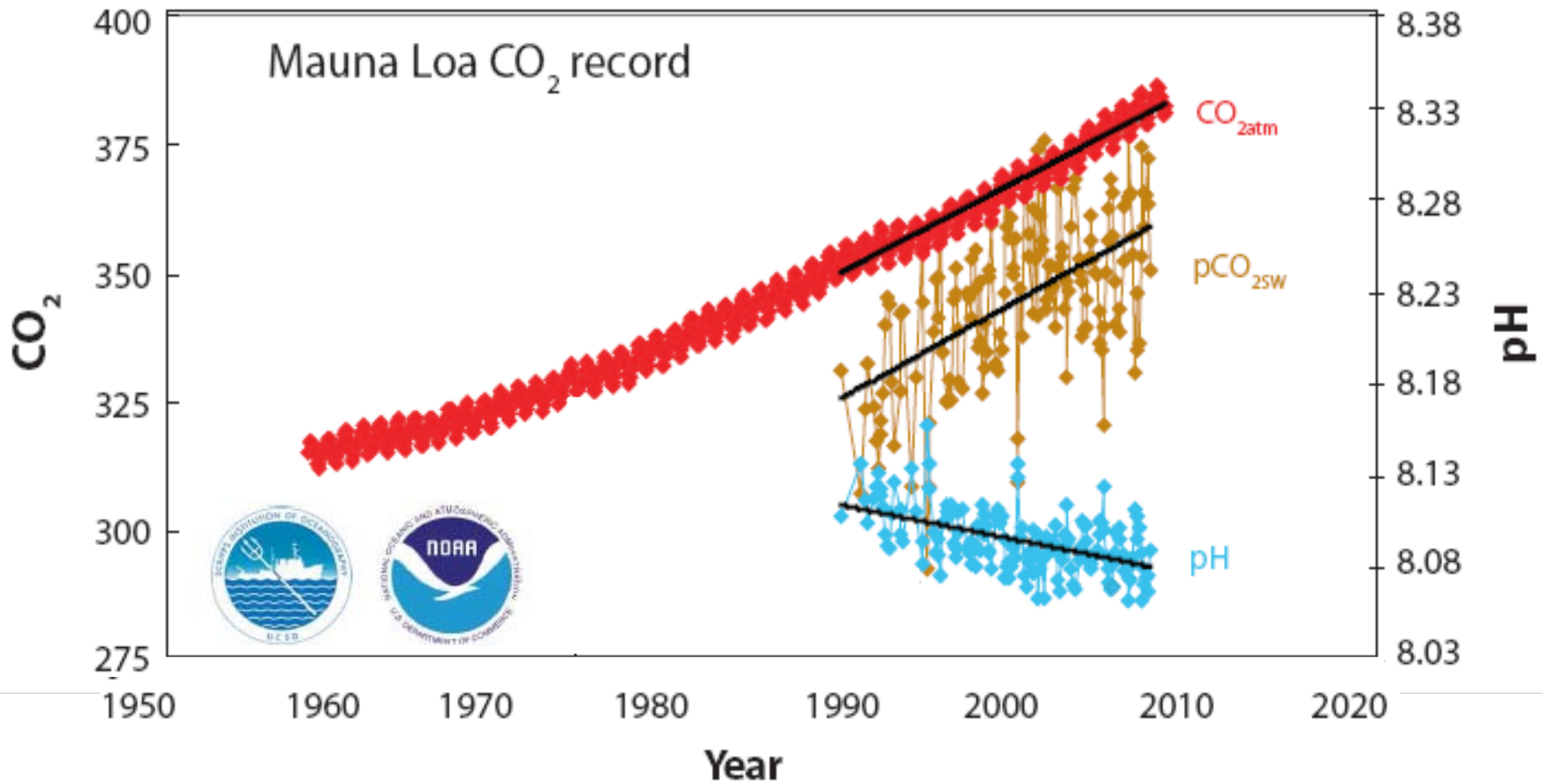
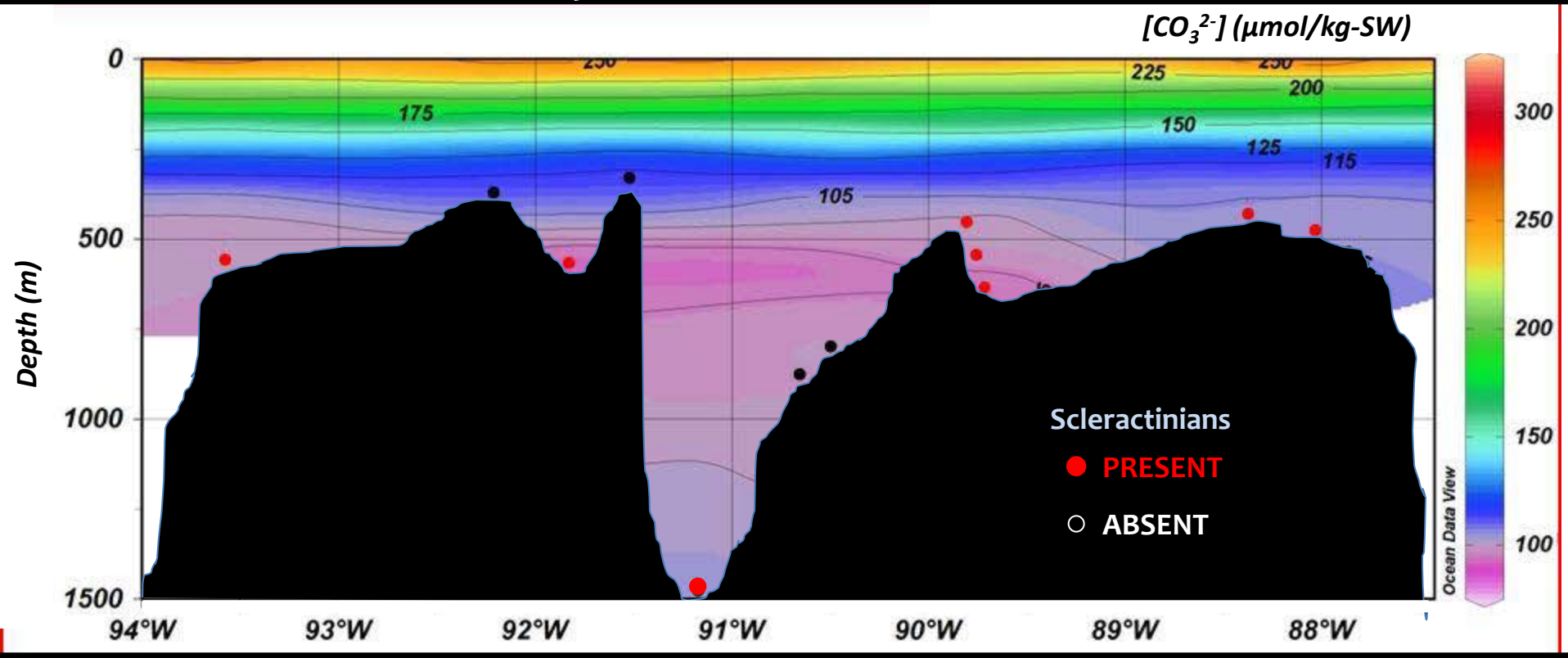


Carbonate Ion Concentration [CO_3^{2-}]



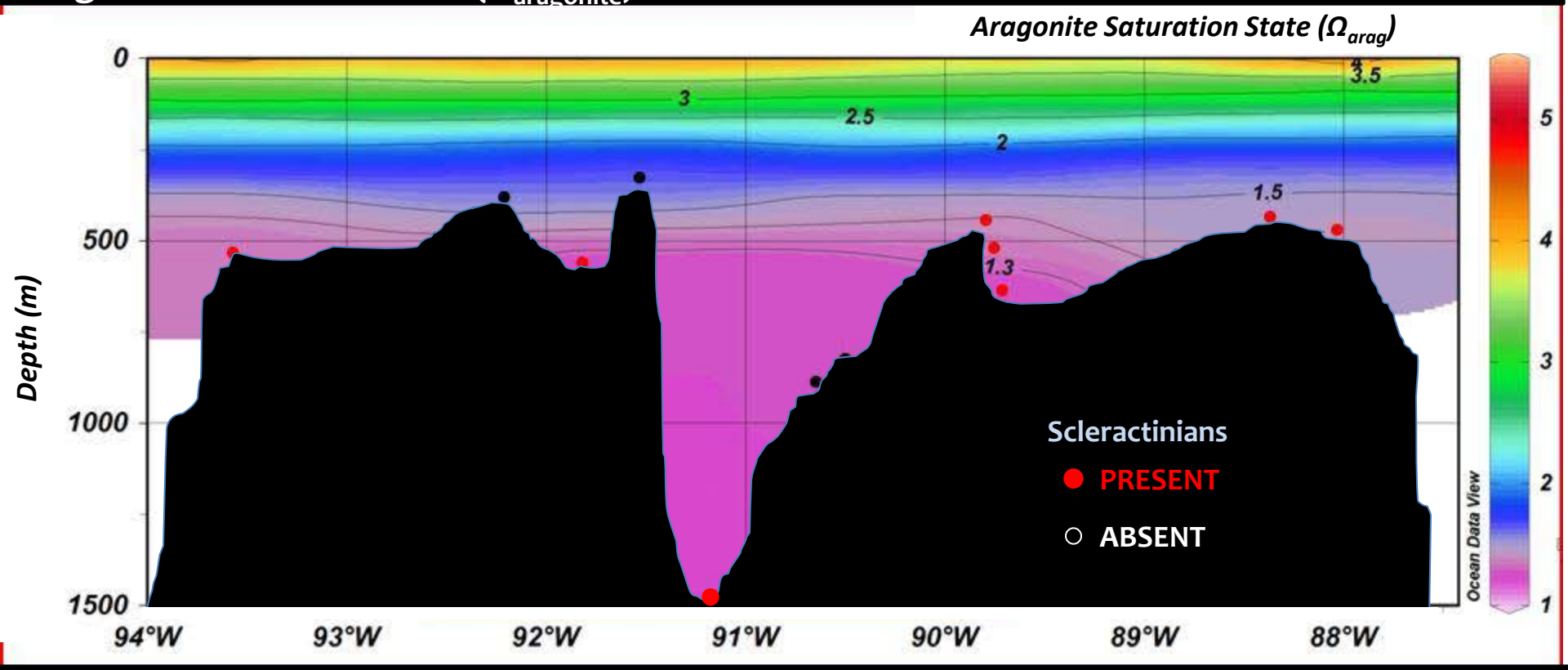
[CO_3^{2-}] at coral sites: 92-123 µmol/kg-SW
shallow-water coral reefs: ~210-240 µmol/kg-SW

[HCO_3^-] at coral sites: 2014-2093 µmol/kg-SW
shallow-water coral reefs: ~2000 µmol/kg-SW

no documented coral reefs at [CO_3^{2-}] < 200 µmol/kg-SW

Scientific Synthesis of the Impacts of Ocean Acidification on Marine Biodiversity (2009)

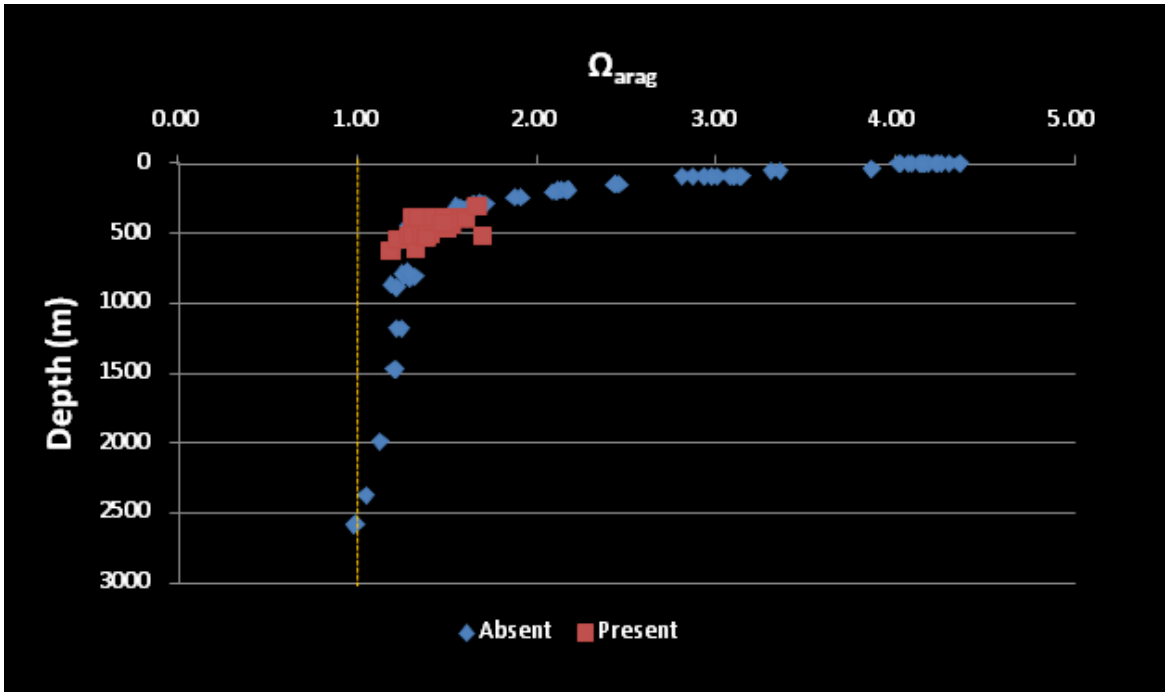
Aragonite Saturation State ($\Omega_{aragonite}$)



$\Omega_{aragonite}$ at coral sites: 1.28-1.69

Aragonite Saturation State ($\Omega_{aragonite}$)

Aragonite Saturation State (Ω_{arag})



$\Omega_{aragonite}$ at coral sites: 1.28-1.69

$\Omega_{aragonite}$ declines with respect to depth (and temperature)

Undersaturation of aragonite detected at ~2500 m

Summary Points …

Baseline values for TA, pH_T, $[CO_3^{2-}]$, $[HCO_3^-]$,and Ω_{arag} established for deep waters of GoM at cold-water coral sites

- TA = 2300-2340 µmol/kg-SW
- pH (*in situ*) = 7.85-7.95
- $[CO_3^{2-}]$ = 92-123 µmol/kg-SW
- $[HCO_3^-]$ = 2014-2093 µmol/kg-SW
- Ω_{arag} = 1.28-1.69

Documentation of scleractinian coral reefs at lowest Ω_{arag} yet published

- Manzello (2010) reports minimum Ω_{arag} ~ 1.54 at Galapagos coral reefs

ASH apparently at ~2,500 m, but we need more samples

References

Guinotte, J.M., J. Orr, S. Cairns, A. Freiwald, L. Morgan, and R. George. 2006. Will human-induced changes in seawater chemistry alter the distribution of deep-sea scleractinian corals? Front. Ecol. Environ. 4:141–146.

Manzello, D.P. 2010. Ocean acidification hot spots: Spatiotemporal dynamics of the seawater CO_2 system of eastern Pacific coral reefs. Limnol. Oceanogr. 55:239–248.

Sabine, C.L., R.A.Feely, N. Gruber, R.M. Key, K. Lee, J.L. Bullister, R. Wanninkhof, C.S. Wong, D.W.R. Wallace, B. Tilbrook, F.J. Millero, T.H. Peng , A. Kozyr, T. Ono, and A.F. Rios. 2004. The oceanic sink for anthropogenic CO_2. Science 305:367–371.

Secretariat of the Convention on Biological Diversity. 2009. Scientific synthesis of the impacts of ocean acidification on marine biodiversity. Montreal: Technical Series No. 46. 61 pp.