Impacts of Ocean Acidification on Coral Reefs

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NOAA Coral Reef Watch

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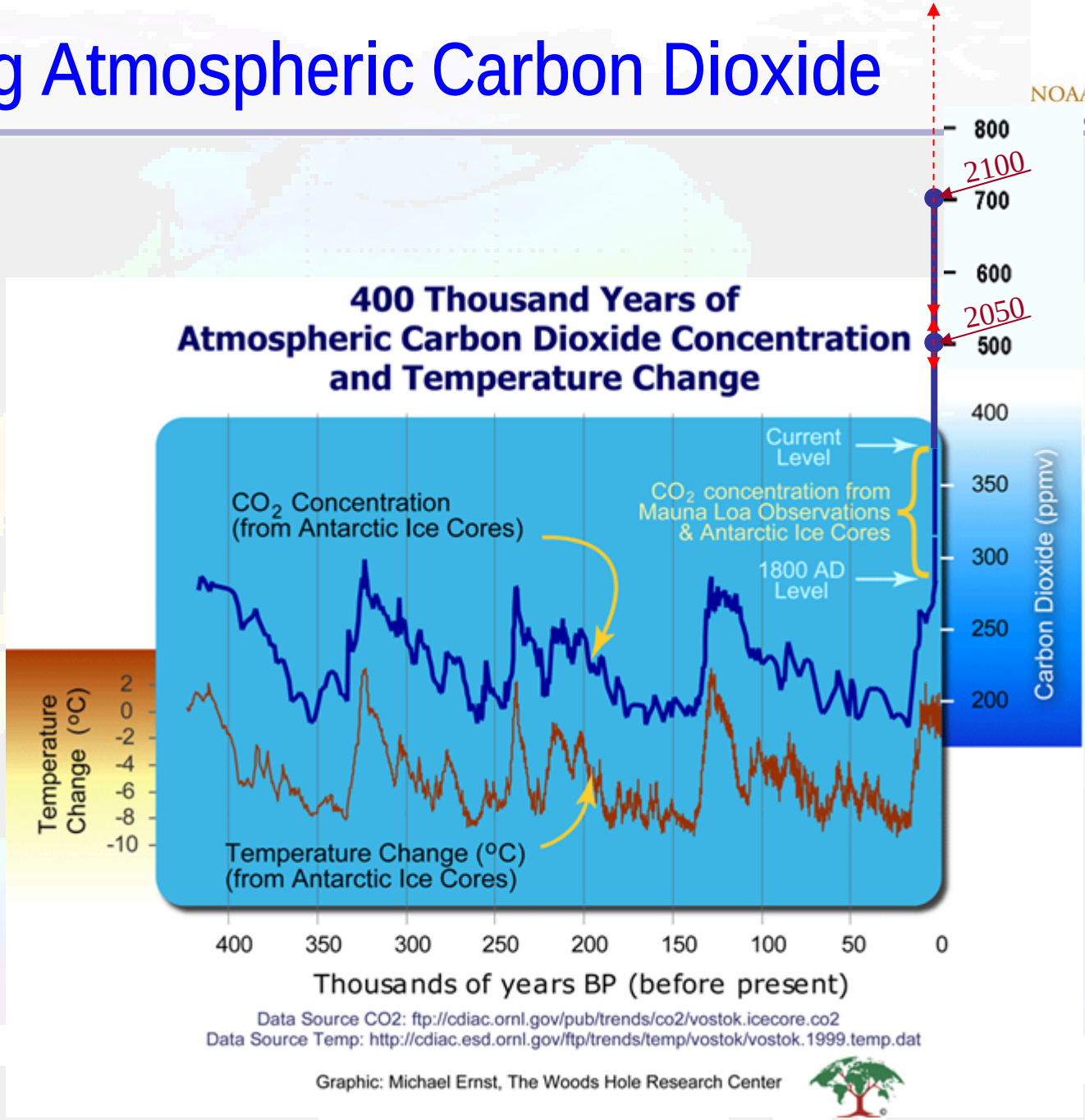
- Ocean chemistry is changing to a state that has not occurred for hundreds of thousands of years
- Shell-building in marine organisms may slow down
- Reef-building may decrease, stop, or reverse
- Fundamental changes may occur in open-ocean and coastal marine ecosystems

Take Home Points:

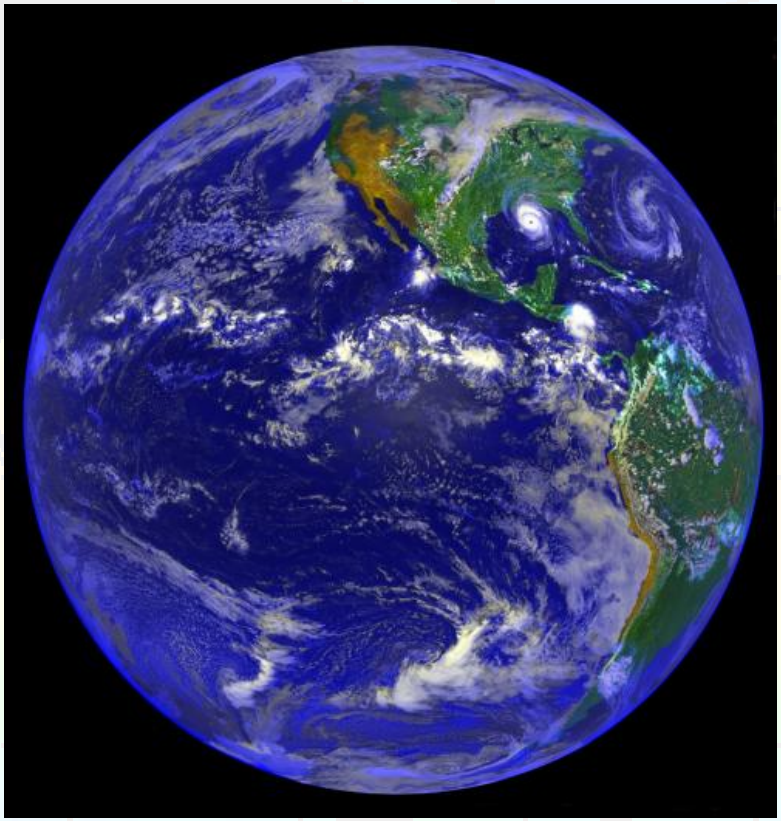
- **Ocean acidification is a growing problem**
- **It will be significant for reef corals within a few decades**
- **Studies and monitoring are needed now to understand impacts**

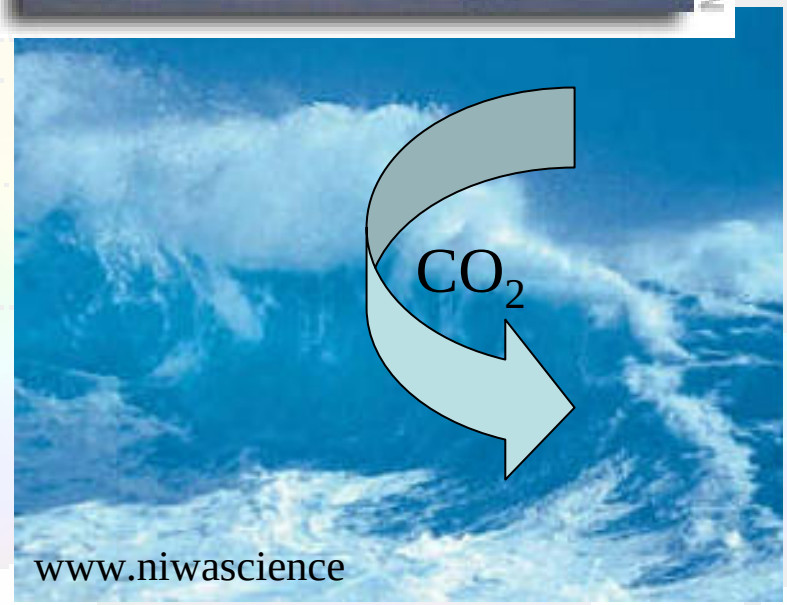
Rising Atmospheric Carbon Dioxide



Current CO_2 highest in 650,000 years of ice core data and 24 million years from soil data

Surface Ocean Uptake of CO_2



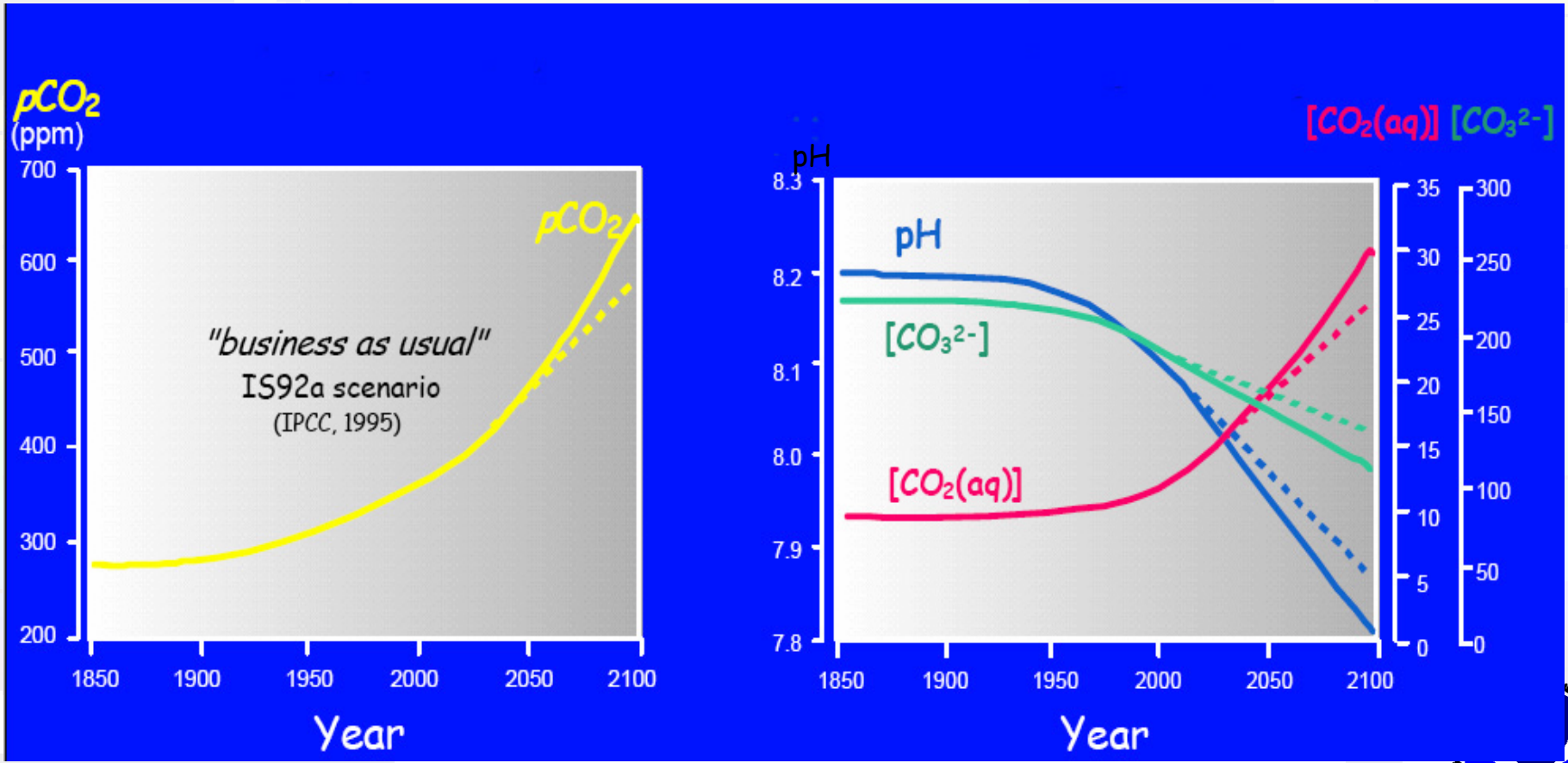


≈ 48% of anthropogenic CO_2 taken up by the ocean

Rising atmospheric CO_2 is changing the chemistry of the oceans

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

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



After Wolf-Gladrow et al., 1999

The Ocean in a High CO_2 World

An International Science Symposium
May 10-12, 2004
UNESCO, Paris, France

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SYMPOSIUM ON THE OCEAN IN A HIGH-CO_2 WORLD
PARIS
10-12 MAY 2004

Workshop on the Impacts of Increasing Atmospheric CO2 on Coral Reefs and Other Marine Calcifiers

18-20 April 2005
USGS Center for Coastal and Watershed Studies
St. Petersburg, Florida

THE ROYAL SOCIETY

30 June 2005

June, 2005

Ocean acidification due to increasing atmospheric carbon dioxide

Identified priority research areas and recommended approaches from small-scale laboratory experiments to large-scale field experiments, and modeling.

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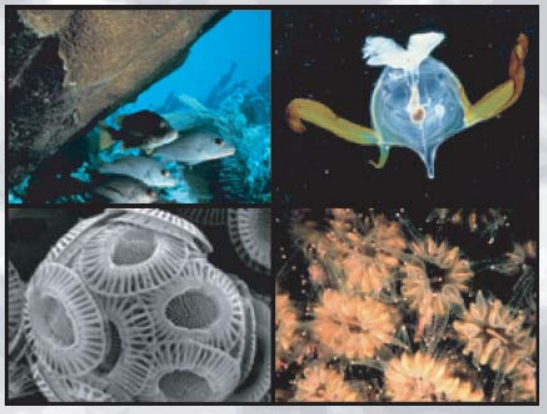
Impacts of Ocean Acidification on Coral Reefs and Other Marine Calcifiers

A Guide to Future Research



Report of a workshop sponsored by

NSF NOAA USGS

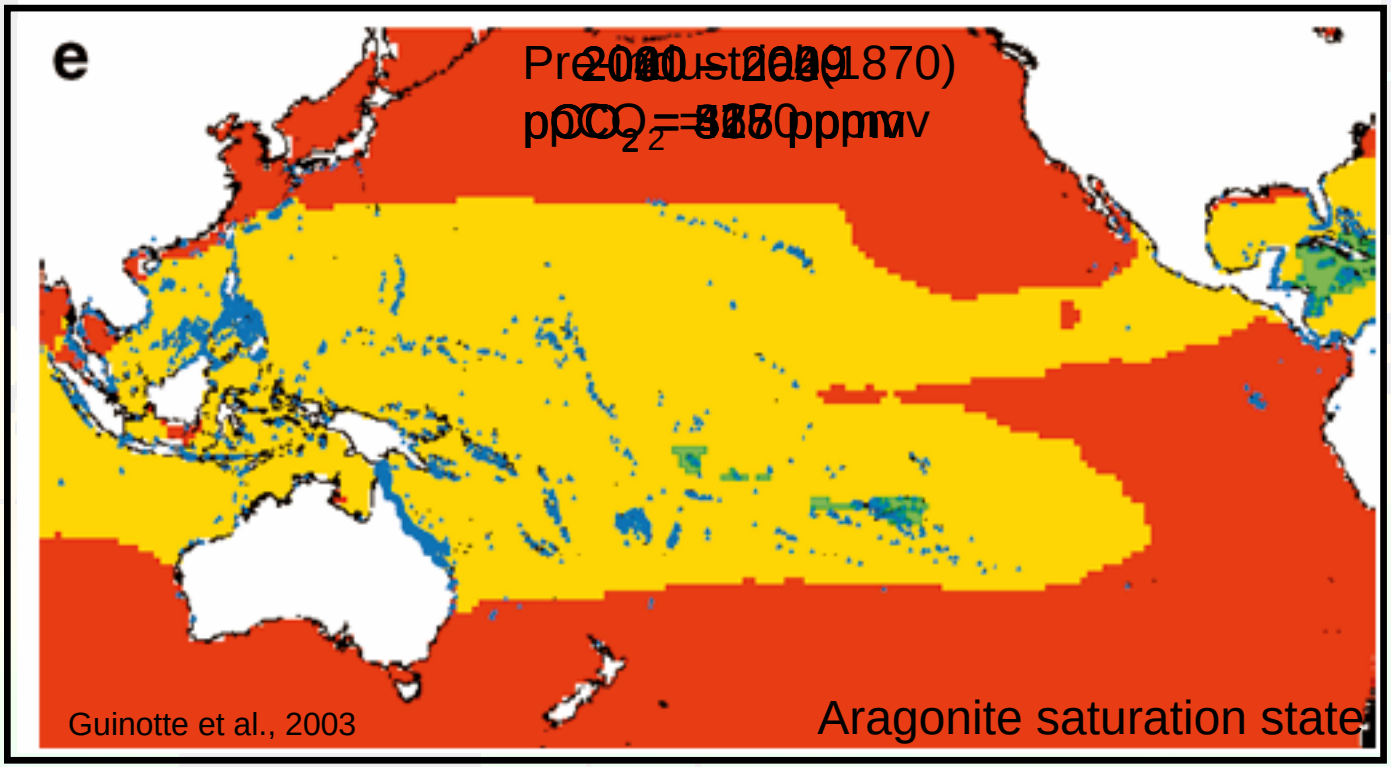
JA Kleypas . RA Feely . VJ Fabry
C Langdon . CL Sabine . LL Robbins

NSF NOAA USGS science for a changing world

Report released
June 2006

NOAA National Oceanic and Atmospheric Administration U.S. Department of Commerce

Ability of Coral Reefs to Calcify



Aragonite Saturation State

- > 4
- 3.5 - 4
- 3 – 3.5
- < 3
- No Data

NCAR Community Climate System Model CCSM v 1.0
IPCC SRES B2 scenario

Saturation state in the tropics may decrease by 30% over the next century with a proportional reduction in calcification rates

Experiments on Many Scales

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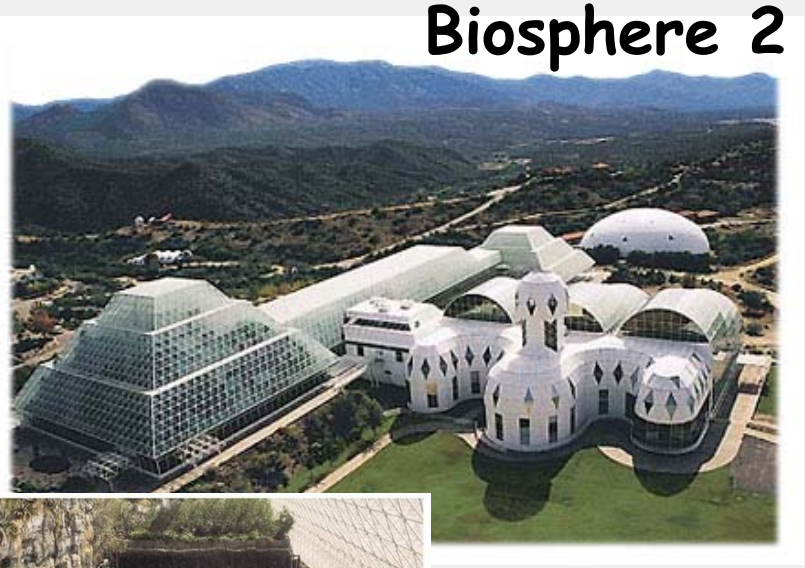
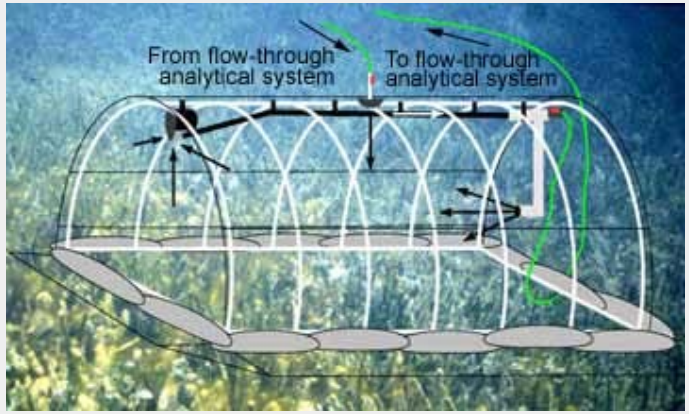
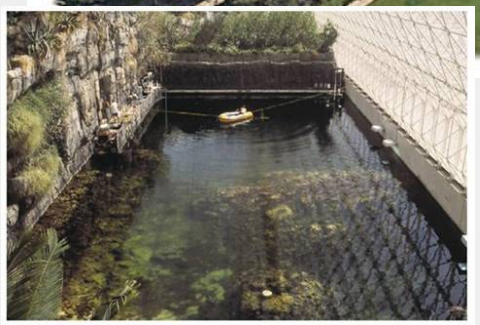
Biosphere 2







SHARQ

Submersible Habitat for Analyzing Reef Quality

Aquaria and Small Mesocosms

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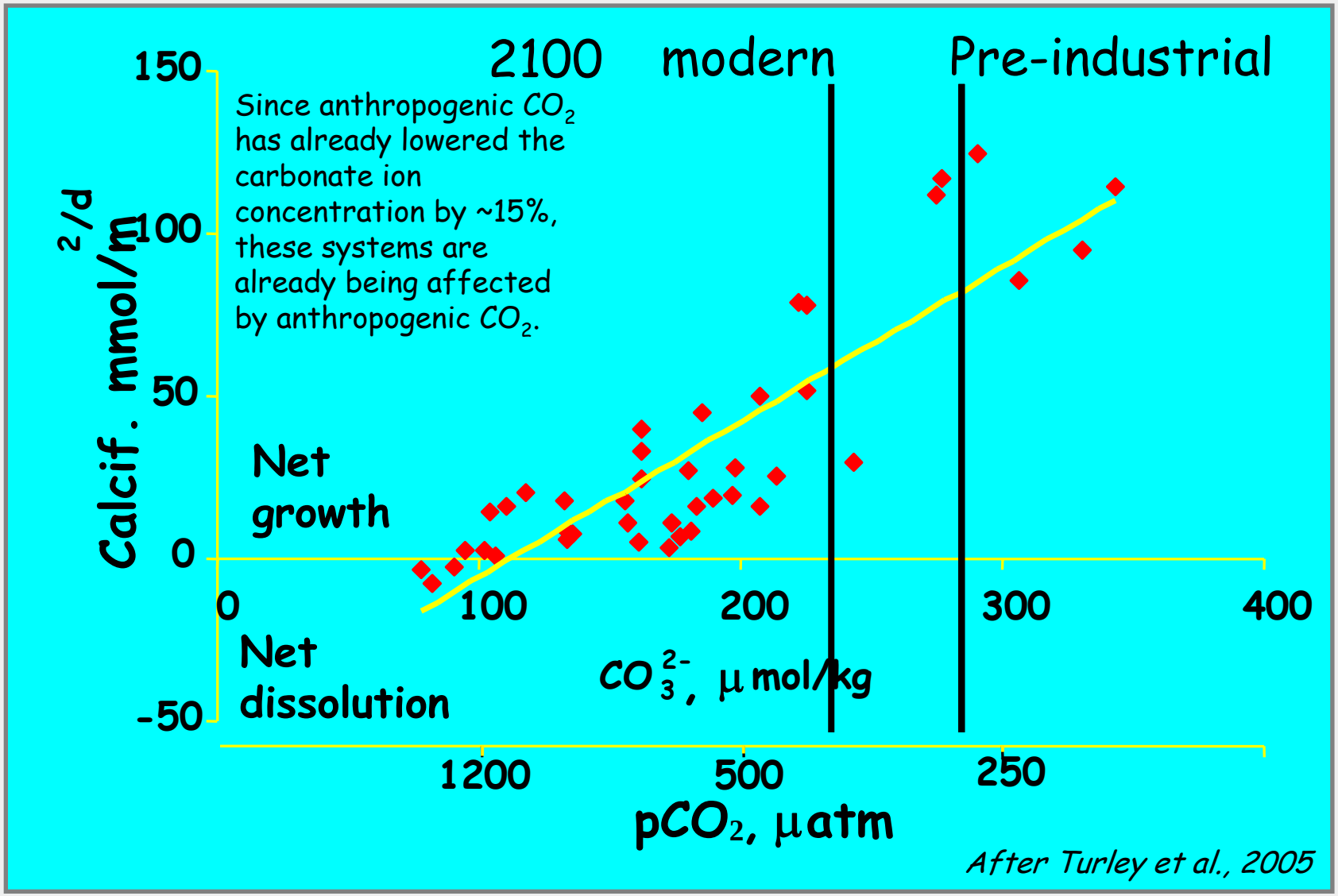
Measured responses of marine calcifying organisms to increased pCO_2

Organism	% Change in Calcification at 2X Preindustrial pCO_2	3X Preindustrial pCO_2
Reef-building corals (Scleractinian corals)		
Acropora cervicornis	-40	-59
Acropora verweyi	-12	-18
Fungia sp.	-47	-69
Galaxea fascicularis	-56	-83
Pavona cactus	-14	-20
Porites compressa	-17	-25
Porites lutea	-38	-56
Porites porites	-16	
Stylophora pistillata	-14	-20
Turbinaria reniformis	- 9	-13
Coralline red algae		
Porolithon gardinerieri	-25	
Carbonate reef systems		
Biosphere 2	-56	-83
Monaco mesocosm	-21	
Monaco mesocosm	-15	

Linear Decrease in Calcification with Increasing Ocean CO_2



Ocean Acidification: Impacts on Corals and Reefs

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3 Options for Corals:

- Grow (extend) more slowly
- Build more brittle skeletons
- Divert energy from other processes (reproduction, healing damage, etc.)

Result is:

- Changed balance between construction and erosion
- Reduced ability to keep up with rising sea level

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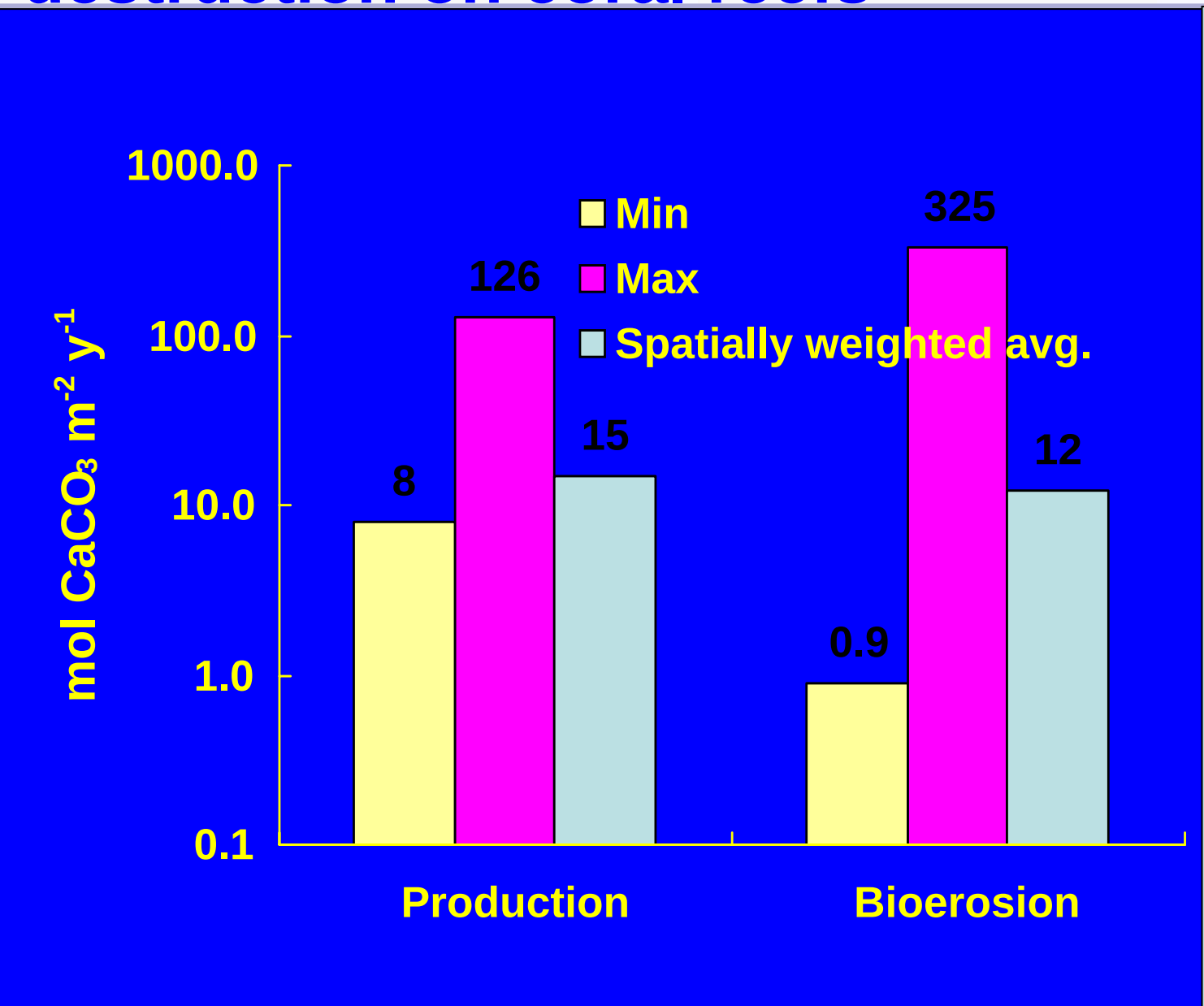
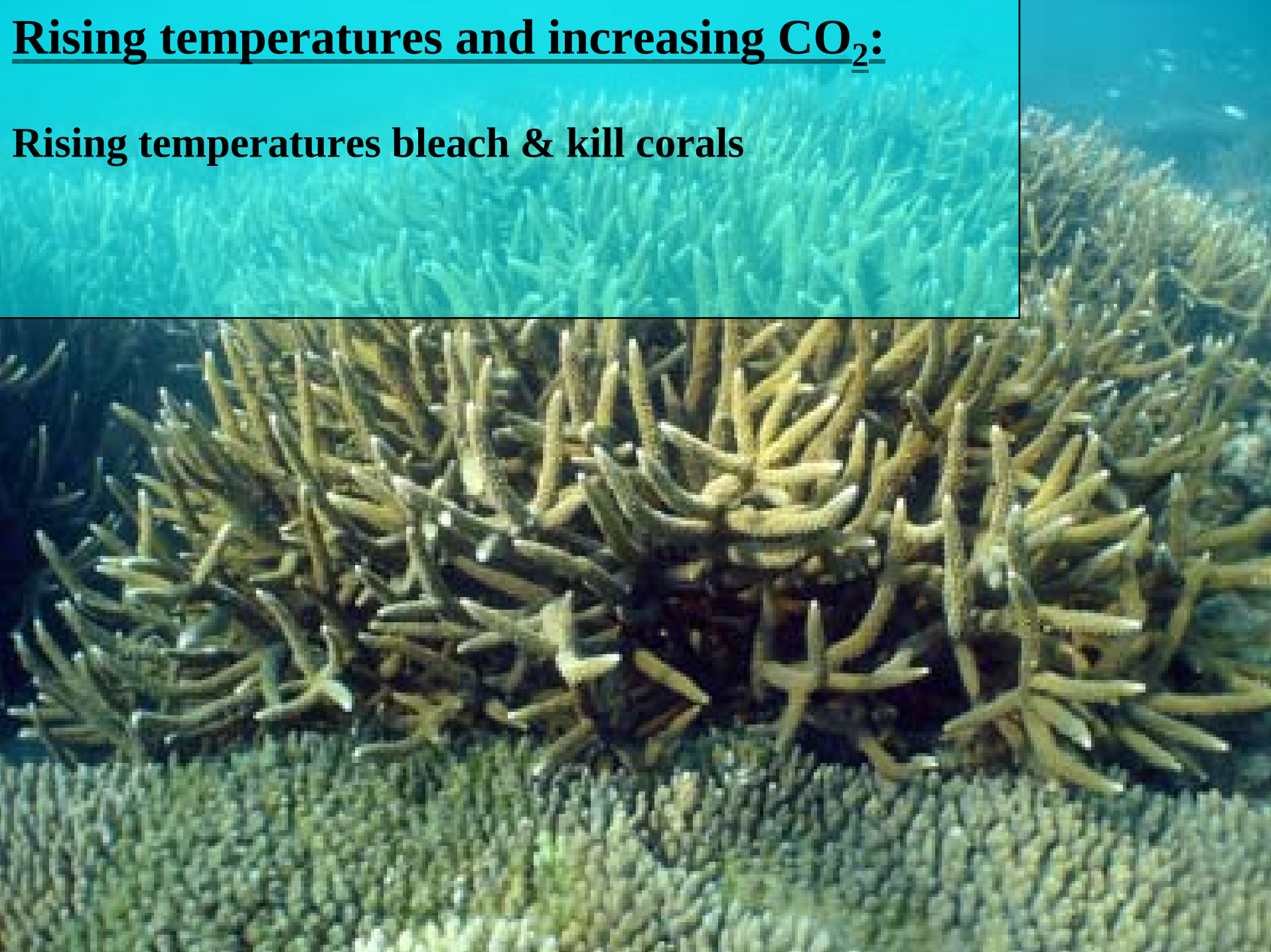
Balance of carbonate production and destruction on coral reefs



A reduction in calcification of 20% could push many coral reefs into a negative mass balance.

Rising temperatures and increasing CO_2:

Rising temperatures bleach & kill corals



Rising temperatures and increasing CO_2:

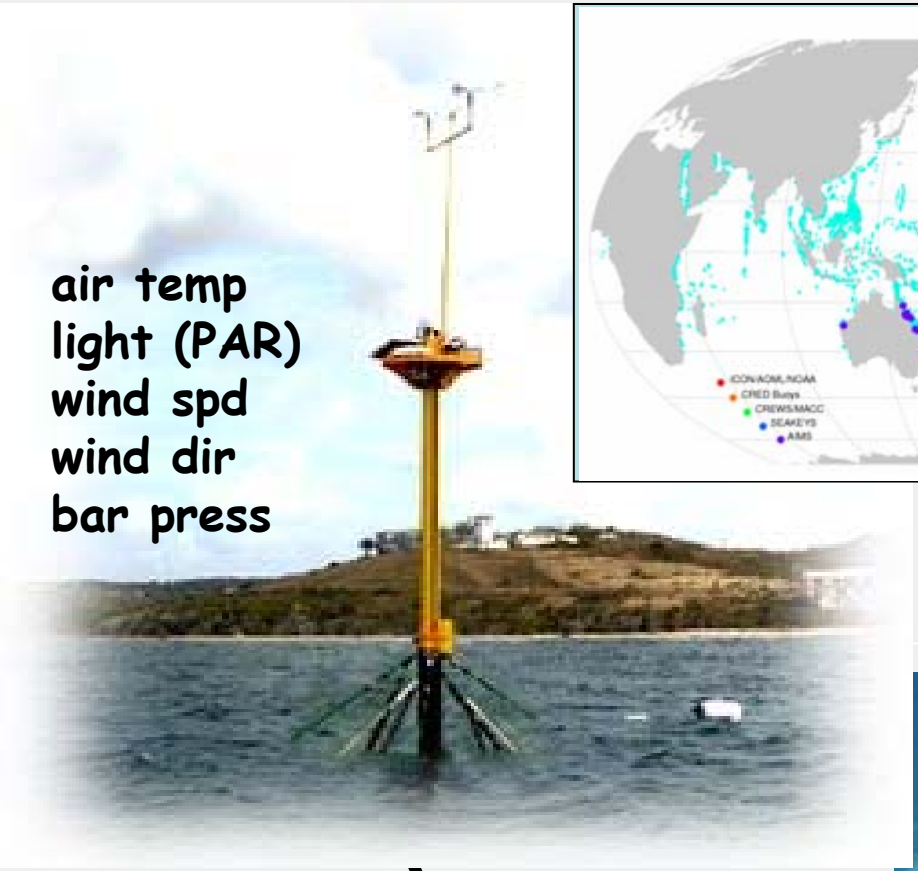
Rising temperatures bleach & kill corals

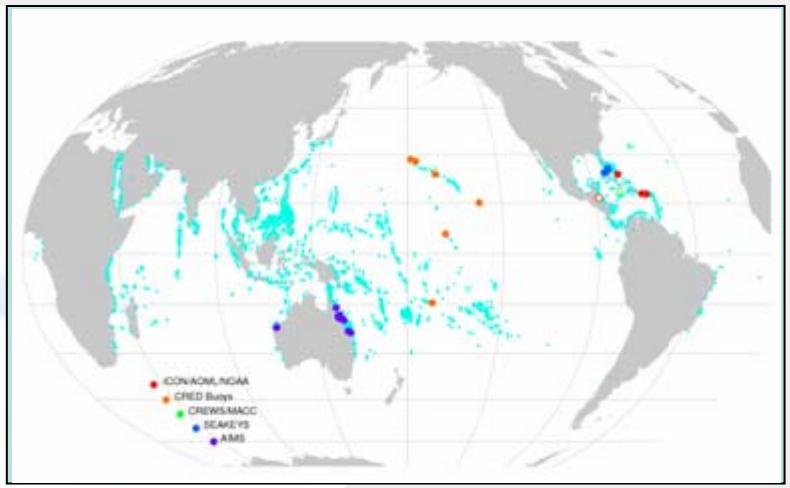
Rising temperatures and increasing CO_2:

Rising temperatures bleach & kill corals

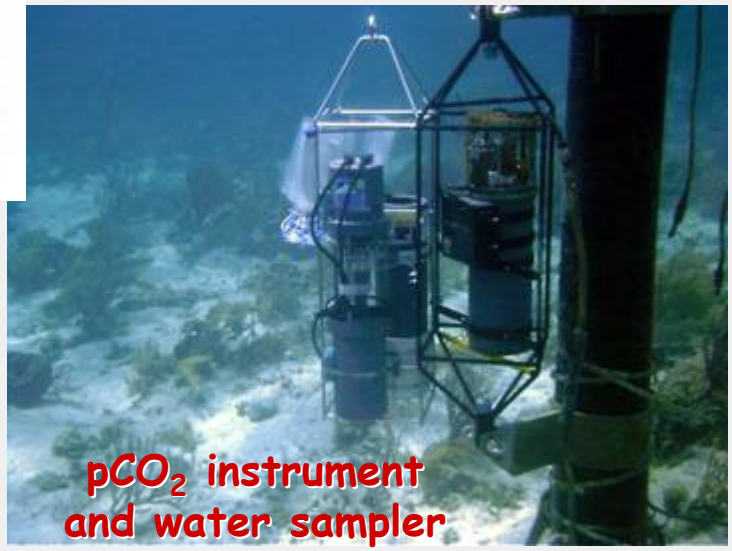
Rising CO_2 threatens reef structure

NOAA Reef Seawater Chemistry Monitoring





water temp
salinity
light (PAR & UVB)
conductivity



NOAA CO_2 Buoy in Kaneohe Bay

- P_{CO2} of air and water
- Salinity
- Temperature
- O_2 of air and water

Critical Research Needs

- **Calcification response across multiple taxa**

  Corals, coralline algae

  tropical reef ecosystems, cold-water corals

  ecosystem-wide and biodiversity impacts

- **Capacity to adapt to decreased $CaCO_3$ saturation**

  Some corals shift chemistry, but grow slower

- **Shifts in latitudinal distributions?**

- **Effects of multiple controls on calcification**

  (e.g., pCO_2, T, light, nutrients)

- **Monitoring of CO_{2atm} and pCO_2 on reefs**

Ecosystem Effects
Food webs
Competition
$CaCO_3$-dependent communities

Organism Effects
Fitness & survival
Multiple life-stages
Adaptation

Calcification
Interaction with T, Irradiance, Nutrients
Calcification mechanisms
Calcification-Photosynthesis Link

Take Home Points:

- Ocean acidification is a growing problem
- It will be significant for reef corals within a few decades
- Studies and monitoring are needed now to understand impacts
- Global-scale changes in CO_2 outside the control of local managers

- Ocean acidification makes it more critical that we combat stressors that we <u>can</u> address now