Coral, Climate & Culture: an Exploration Seminar in the Marshall Islands

Pre-trip Meeting #2

Wed. May 20, 2009

Prof. Julian Sachs, Director
Michelle Townsend, Asst. Director
Alyssa Atwood, Graduate Student TA
Dan Nelson, Graduate Student TA

Agenda

- A few housekeeping issues
- Academic aspects of the course:
  - Syllabus
  - Assignments
  - Grading and evaluation
  - Daily schedule of activities
- Brief presentations on
  - Coral disease
  - Crown of Thorns Starfish problem
  - *Tridacna* spp.
  - Climate issues facing the RMI

“Housekeeping” Issues

- Medical forms to Michelle
- Travel info to Michelle
- Emergency information sheet & card
- Code of conduct form (*see next slide*)

Revised Code of Conduct

- After much thought we are changing the following to *Recommendations* from *Requirements*:
  - Curfew
  - Buddy system
  - Evening sign-in
- Not changed
  - Prohibition of guests in CMI dorms
  - Cultural sensitivity, esp. regarding dress & behavior (as discussed at last mtg.)

Academics

- *Distribute syllabus*

Assignments - 1

- **Oral presentation** to Marshallese officials & citizens
  - Four teams of 5 to discuss following Climate Change topics: Greenhouse gas emissions, Temperature projections (21st century), sea level projections (21st century), ocean acidification & coral mortality, regional / local impacts.
  - Prof. Sachs will put together the Powerpoint slides and distribute hardcopies to each student. Teams of students need to meet and come up with the narrative, then divide up the topics to be orally presented amongst team members.

Assignments - 2

- **Term Paper** on the climate threat to the Marshall Islands and the Marshallese people.
  - The expected impacts on the land, the sea and the coral reefs.
  - Also address what the Marshallese might be able to do to adapt to these changes.
  - Incorporate the observations and experiences you had while in the RMI
  - 10 pages
  - Due 9/1/09

Assignments - 3

- **Course evaluation**
  - What you learned, liked & disliked
  - What would have made your experience better?
  - What detracted from it?
  - 3-5 pages
  - Due 7/20/09

Course Credit

- **Credits Offered**
  - This program will offer a total of 6 credits
    - Five (5) credits of one of the following
      - » OCEAN 494, Field Experience (NW)
      - » OCEAN 496, Study Abroad (NW)
      - » OCEAN 497, Advanced Special Topics (NW)
    - Plus one (1) credit of
      - » GEN ST 392

Grading

- Numeric (0-4 scale)
- Oral Presentation(s) in Majuro 30%
- Term Paper 30%
- Participation in Class & Activities 40%

(Strongly) Suggested Readings

- You are encouraged to read articles & papers we post on course website *before the* trip to enhance your learning experience & prepare you for your presentation & term paper
  - *The State of Coral Reef Ecosystems of the Republic of the Marshall Islands*
  - *IPCC 2007 Summary for Policymakers (WG1)*
  - *Initial Communication Under The United Nations Framework Convention On Climate Change, Government of the Republic of the Marshall Islands*

Schedule of Activities - 1

- **Morning mtg** in CMI classroom at 8:00 AM
  - 3-5 min summary from each team on previous day activities
  - Plan for the day
  - Short lecture (15-30 mins) on climate, coral or culture
- **Afternoon mtg** (usually in CMI classroom) at 5:00 pm
  - Group discussion about what is working / not working, things we might want to change, schedule or re-schedule, etc.
  - A “feedback session” so we can maximize the learning experience for everyone

Daily Schedule of Activities

DRAFT

Date		Tuesday, June 16	Wednesday, June 17	Thursday, June 18	Friday, June 19	Saturday, June 20	Sunday, June 21
Day		1	2	3	4	5	1
8:00am							
9:00am							
10:00am							
11:00am							
12:00pm							
1:00pm							
2:00pm							
3:00pm							Pick up students at airport, 3:45pm
4:00pm							
5:00pm							BBQ

DIVING
POLICY ACTIVITY
CULTURAL ACTIVI
GROUP MEAL
FREE TIME

Date	Monday, June 22	Tuesday, June 23	Wednesday, June 24	Thursday, June 25	Friday, June 26	Saturday, June 27	Sunday, June 28
Day	2	3	4	5	6	7	8
8:00am	Morning Meeting	Morning Meeting	Morning Meeting	Morning Meeting	Morning Meeting	Morning Meeting	
9:00am	In country Orienation	Site Orientation	Staff members of RMI EPA to speak on climate change issues	Speaker Albon Ishoda (Marshall Islands Marine Resources Authority)		A&B DA #1	
10:00am	Introduce Dean and Mark				Traditional Canoes of the Marshall Islands	C&D DA #2	
11:00am	Present overview of town						
12:00pm	Disperse to grocery stores	Lunch	Lunch	Lunch	Lunch	Lunch	Day Off
1:00pm	Picnic lunch	Site Orientation	A&B DA #1	A&B DA #1		A&B DA #1	
2:00pm	Water/Beach Orientation		C&D DA #2	C&D DA #2		C&D DA #2	
3:00pm	Test snorkel gear				Trip to Giant Clam Farm		
4:00pm	Snorkel activity						
5:00pm	Evening Meeting	Evening Meeting	Evening Meeting	Evening Meeting	Evening Meeting	Evening Meeting	

Date	Monday, June 29	Tuesday, June 30	Wednesday, July 1	Thursday, July 2	Friday, July 3	Saturday, July 4	Sunday, July 5
Day	9	10	11	12	13	14	15
8:00am	Morning Meeting	Morning Meeting	Morning Meeting	Morning Meeting	Morning Meeting	Morning Meeting	
9:00am	Speaker Murray Ford (Sea Grant Coastal Extension Agent)		A&B DA #1	A&B DA #1		Fisherman's Day	
10:00am		Field trip with Murray Ford	C&D DA #2	C&D DA #2			
11:00am					Alele Museum		
12:00pm	Lunch	Lunch	Lunch	Lunch	Lunch	Lunch	Day Off
1:00pm	A&B DA #1	A&B DA #1		A&B DA #1		Fisherman's Day	
2:00pm	C&D DA #2	C&D DA #2	Speaker Steve Why (Marshall Islands Conservation Society)	C&D DA #2			
3:00pm					Cultural Activity- Music and Art of the RMI		
4:00pm							
5:00pm	Evening Meeting	Evening Meeting	Evening Meeting	Evening Meeting	Evening Meeting	BBQ	

Date	Monday, July 6	Tuesday, July 7	Wednesday, July 8	Thursday, July 9	Friday, July 10	Saturday, July 11	Sunday, July 12
Day	16	17	18	19	20	21	22
8:00am	Morning Meeting	Morning Meeting	Morning Meeting	Morning Meeting			
9:00am	A&B DA #1		Student Climate Change Presentations to Marshallese (TBD)				
10:00am	C&D DA #2	Student Practice Presentations		Depart for Arno	Arno	Arno	Arrive in Majuro
11:00am							
12:00pm	Lunch	Lunch	Lunch				
1:00pm	A&B DA #1	A&B DA #1	A&B DA #1				
2:00pm	C&D DA #2	C&D DA #2	C&D DA #2				
3:00pm							
4:00pm							
5:00pm	Evening Meeting	Evening Meeting	Evening Meeting			Banquet	

Date	Monday, July 13
Day	17
8:00am	Morning Meeting
9:00am	Pack
10:00am	
11:00am	
12:00pm	
1:00pm	
2:00pm	
3:00pm	
4:00pm	
5:00pm	Depart Majuro, 8:00pm

In Water Actvities

- Biological census on pristine or recovering reef
  - Identify coral, fish & invertebrates within gridded area
  - Baseline study for future changes, or quantitative study of ecosystem recovery (abandoned quarry)
- Coral Disease: characterize its nature & extent
- Crown of Thorns Starfish Removal
- Giant clam (*Tridacna spp.*) survey

Threats to Coral Reefs
(in the Marshall Islands and around the world)

- Crown of Thorns Sea Star (COTS)
- **Bleaching**
- **Disease**
- Tropical Storms
- Coastal Development and Runoff
- Coastal Pollution
- Fishing
- Ships
- Marine Debris
- Invasive Species
- Bombing (military practices)

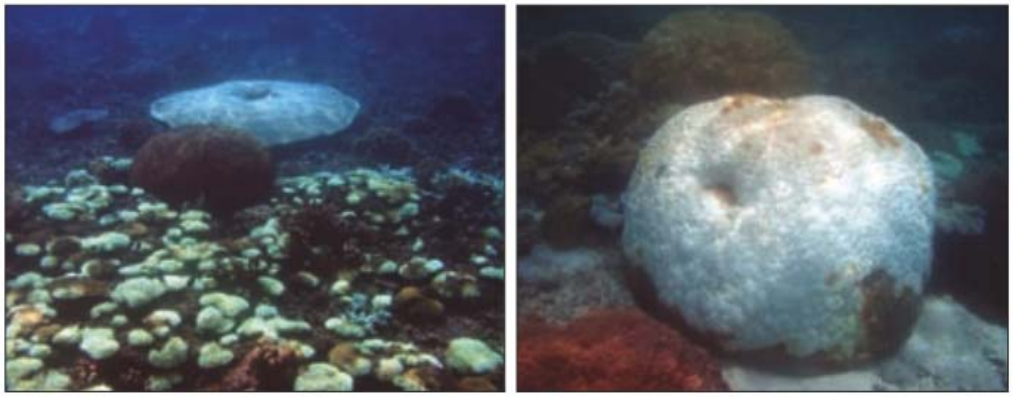


Figure 12.3. In 2006, coral bleaching was documented in Majuro lagoon at the southern reef near the airport (left) and in the northern lagoon (right). Porites *colonies appear to have recovered since then. Photos: D. Jacobson.*

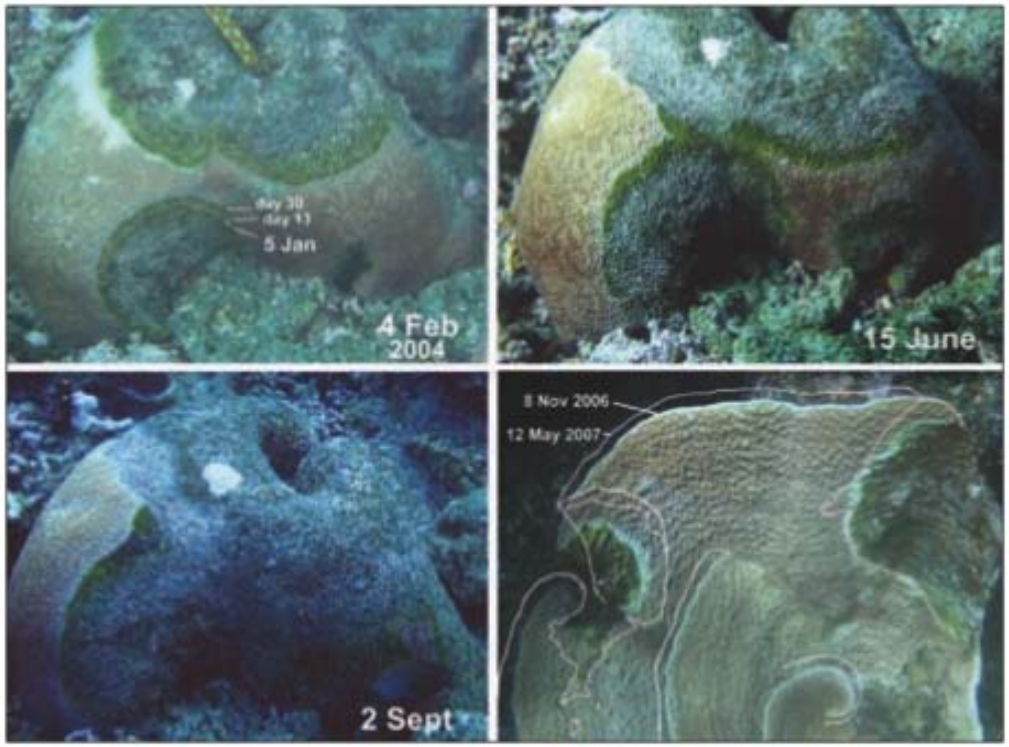


Figure 12.5. Coral disease of unknown etiology affecting Platygyra *(time series) and* Turbinaria. *Outlines show enlargement of lesions and coral growth after six months. Source: D. Jacobson.*

Berger et al., 2008. "**The State of Coral Reef Ecosystems of the Republic of the Marshall Islands**"

What is Coral Bleaching?

Coral bleaching

From Wikipedia, the free encyclopedia

Coral bleaching is the loss of color of corals, due to stress-induced expulsion of symbiotic unicellular algae or due to the loss of pigmentation within the algae[1]. The corals that form the structure of the great reef ecosystems of tropical seas depend on a symbiotic relationship with photosynthesizing unicellular algae called *zooxanthellae* that live within their tissues. Zooxanthellae give coral its particular coloration, depending on the clade living within the coral. Under stress, corals may expel their *zooxantheallae*, which leads to a lighter or completely white appearance, hence the term "bleached". [2]

Coral bleaching is a vivid sign of corals responding to stress which can be induced by any of:

- increased or reduced water temperatures (often attributed to global warming)[3]
  - increased solar irradiance (photosynthetically active radiation and ultraviolet band light) [4]
- changes in water chemistry (in particular ocean acidification) [5] [6]
- starvation caused by a decline in zooplankton levels as a result of overfishing.[7]
- increased sedimentation (can be contributed to silt runoff)
- pathogen infections
- changes in salinity

Coral Bleaching in the Marshall Islands

•Marshall Islands corals generally considered to be in excellent condition

•First bleaching event reported on September 19, 2002 on Jaluit and Majuro Atolls by the RMI EPA, but photographic evidence suggests bleaching between 1998-2000

•Note that corals can recover from bleaching events, but recovery is typically slow

Image from the Florida Keys
http://www.stormcenter.com/media/envirocast/archive/060912/

What is Coral Disease?

- Many types of coral disease exist
  - Black band disease
  - White syndrome
  - Skeletal eroding band
  - Brown band
  - Black necrosing syndrome
  - Pink spot
  - Coral tumors

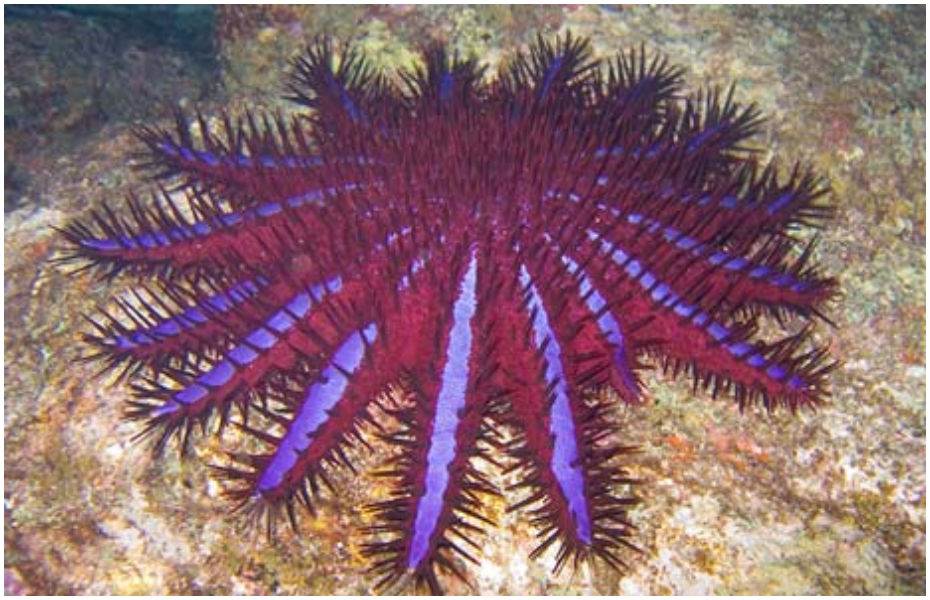
- Coral disease in the Marshall Islands is not well characterized, but diseased corals are observed

- Disease incidence low in Marshall Islands corals as compared to other locations in the world

Black Band Disease

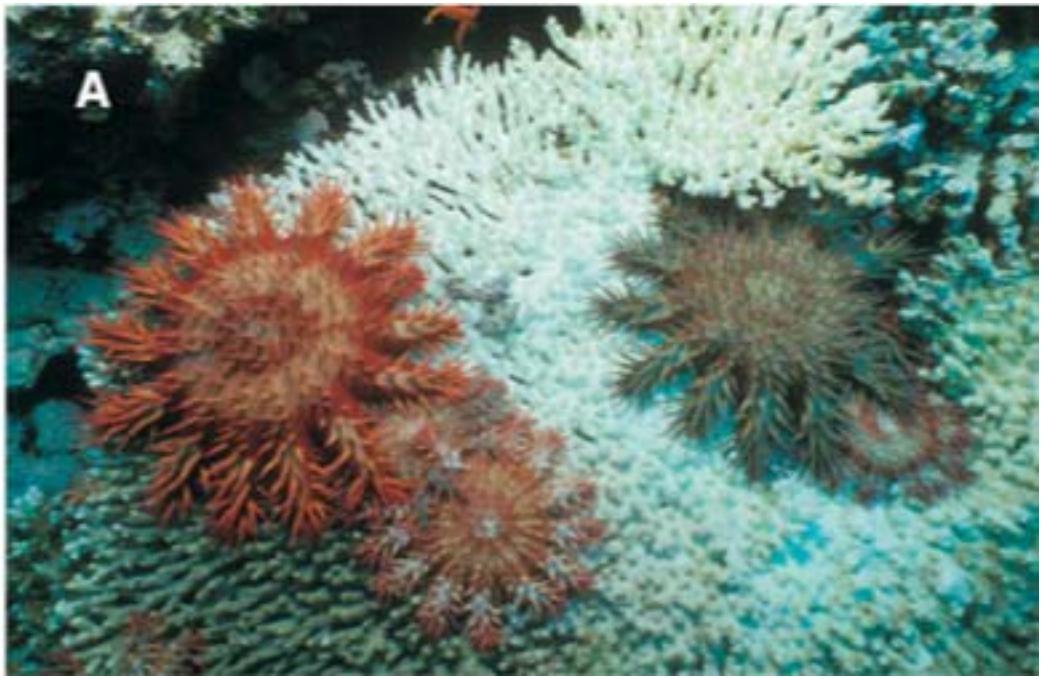
- Bacteria that cause this disease was isolated from Majuro Lagoon in 2004 (Berger et al., 2008)

Crown-of-Thorns Starfish (COTS)



- The crown-of-thorns starfish is an echinoderm with protective spines all over its body, which eject a neurotoxin
- Can grow up to 40 cm in diameter, and is equipped with anywhere from 12 to 19 arms.
- Found in tropical coral reefs from the Red Sea to the Indian & Pacific Oceans
- They devour coral by climbing and extruding their stomach over them in order to excrete a digestive enzyme which transforms the reef into consumable, liquefied tissue.

Coral damage caused by Crown of Thorns starfish



Rotjan et al, 2008

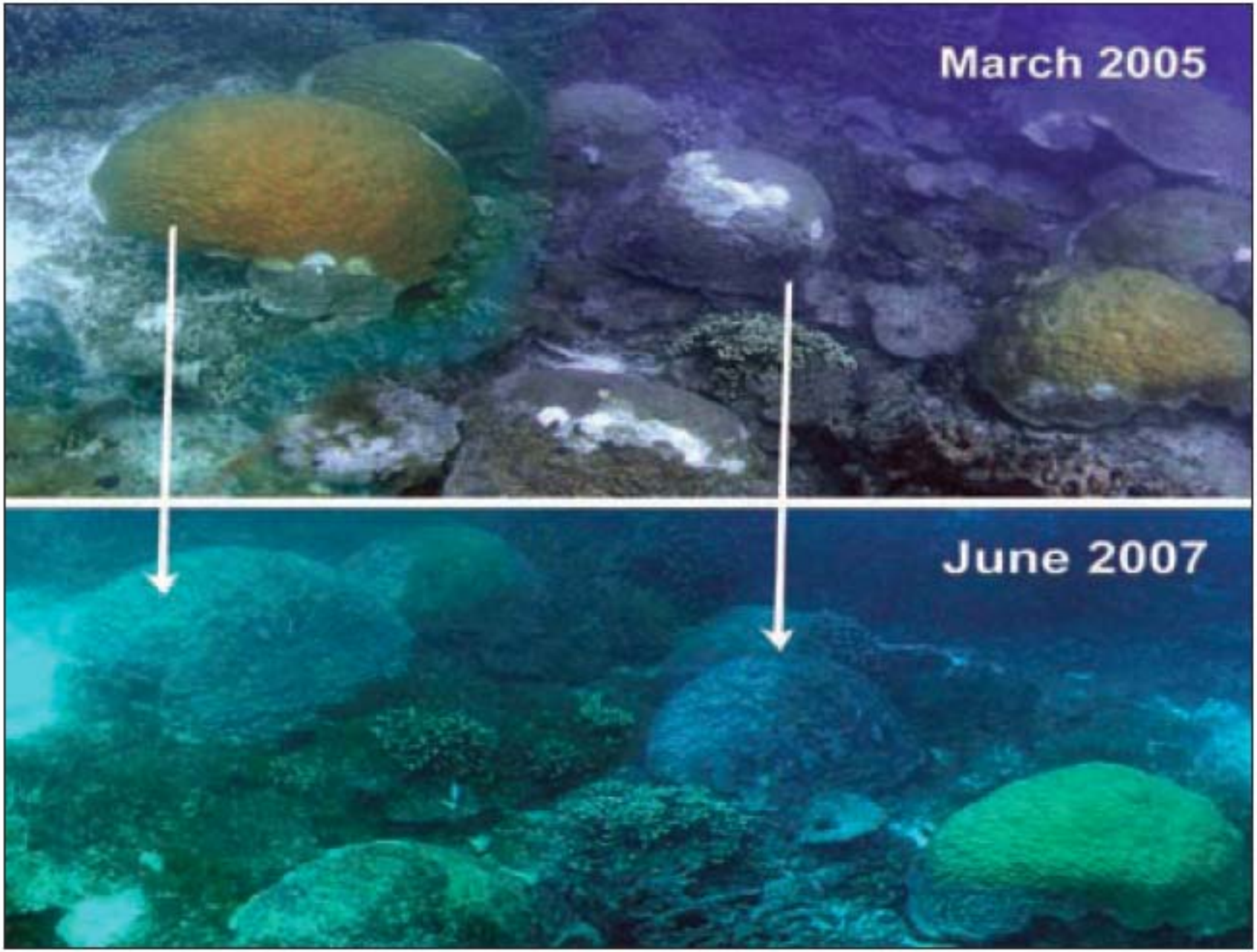
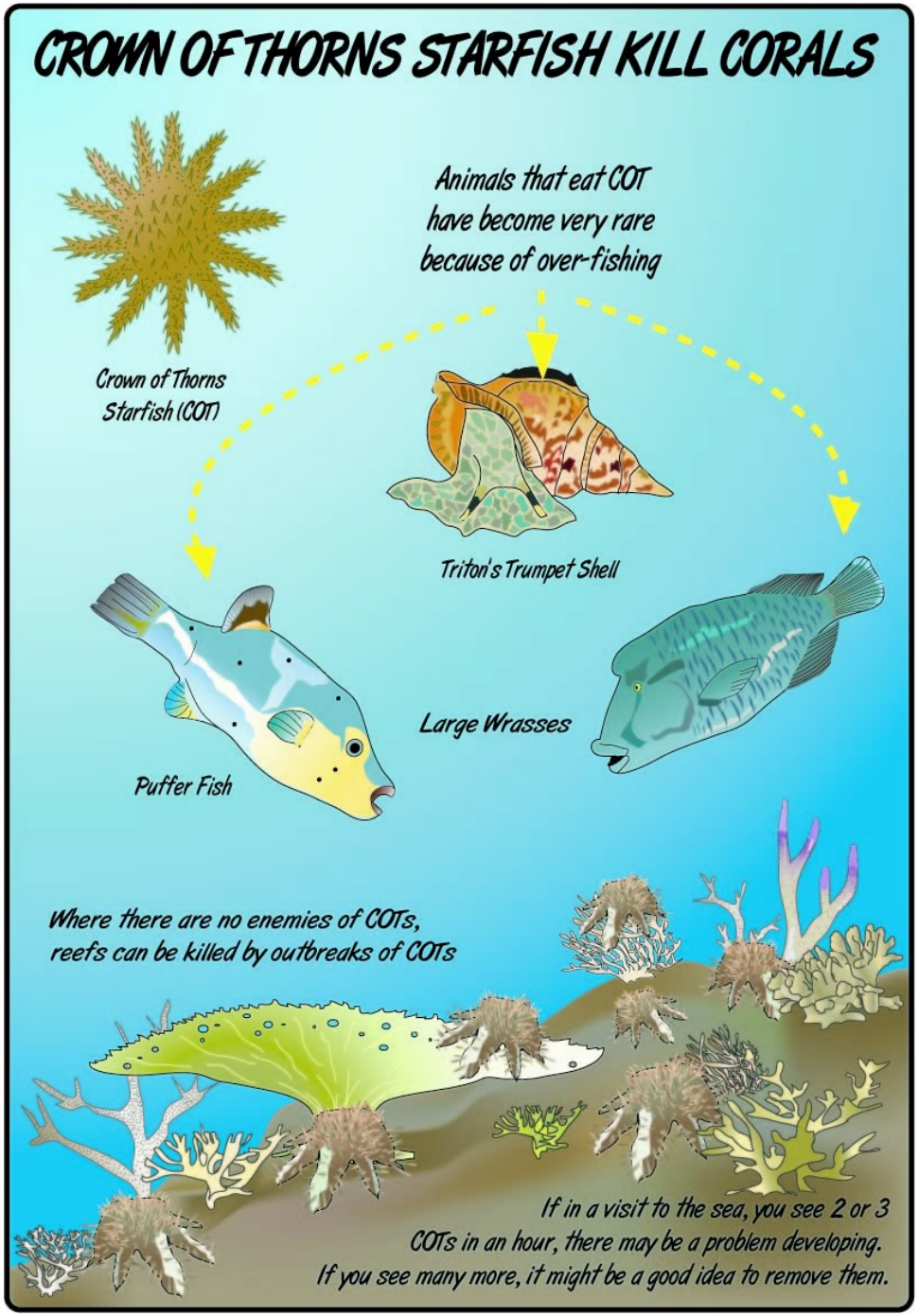


Figure 12.14. Majuro lagoon time series showing demise of large (2-3 m) Porites *colonies from COTS predation. Photos: D. Jacobson.*

Global Distribution of Crown of Thorns

Vogler, 2009



COTS Outbreaks

- Cause remains unknown
  - o Animals that eat COTS are being over-fished
  - o Pollution (agricultural & sewage runoff) increases algal blooms that nourish COTS larvae

Tridacna (“Giant Clam”)

•*Tridacna* is the genus name, many species

•Native to the shallow reefs of South Pacific and Indian Oceans

•Largest living bivalve mollusk

•Reach sizes of up to 4 feet in length and can weigh up to 500 lbs.

•Average lifespan is more than 100 years in the wild

http://en.wikipedia.org/wiki/Giant_clam

Tridacna ("Giant Clam")

•Raised commercially in the Marshall Islands for aquariums

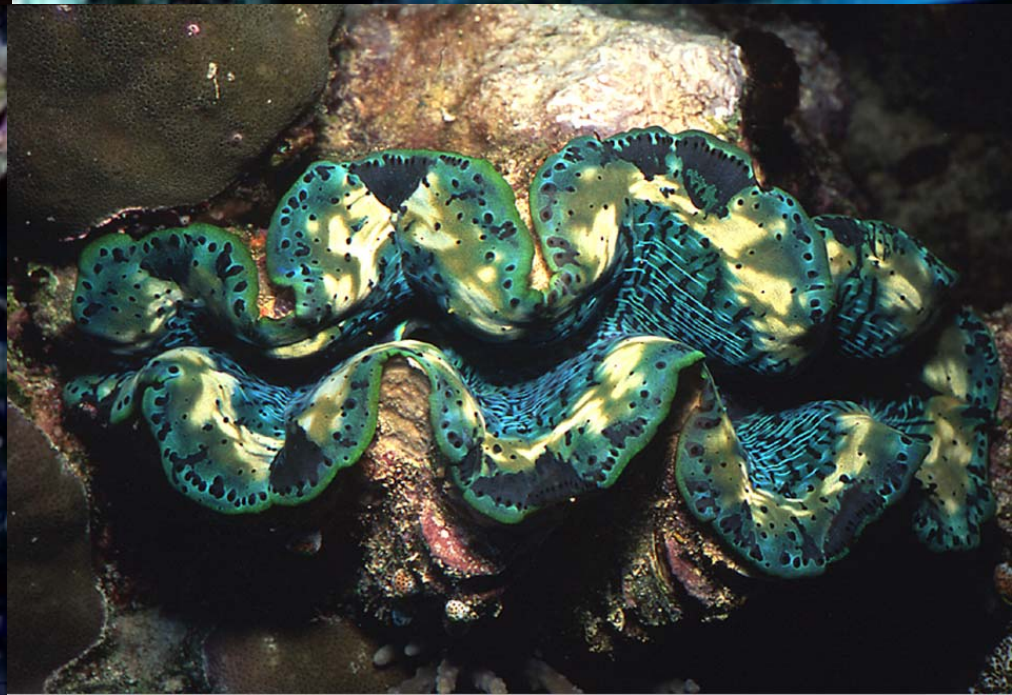
•Some species were introduced to the region(e.g. *Tridacna derasa*)

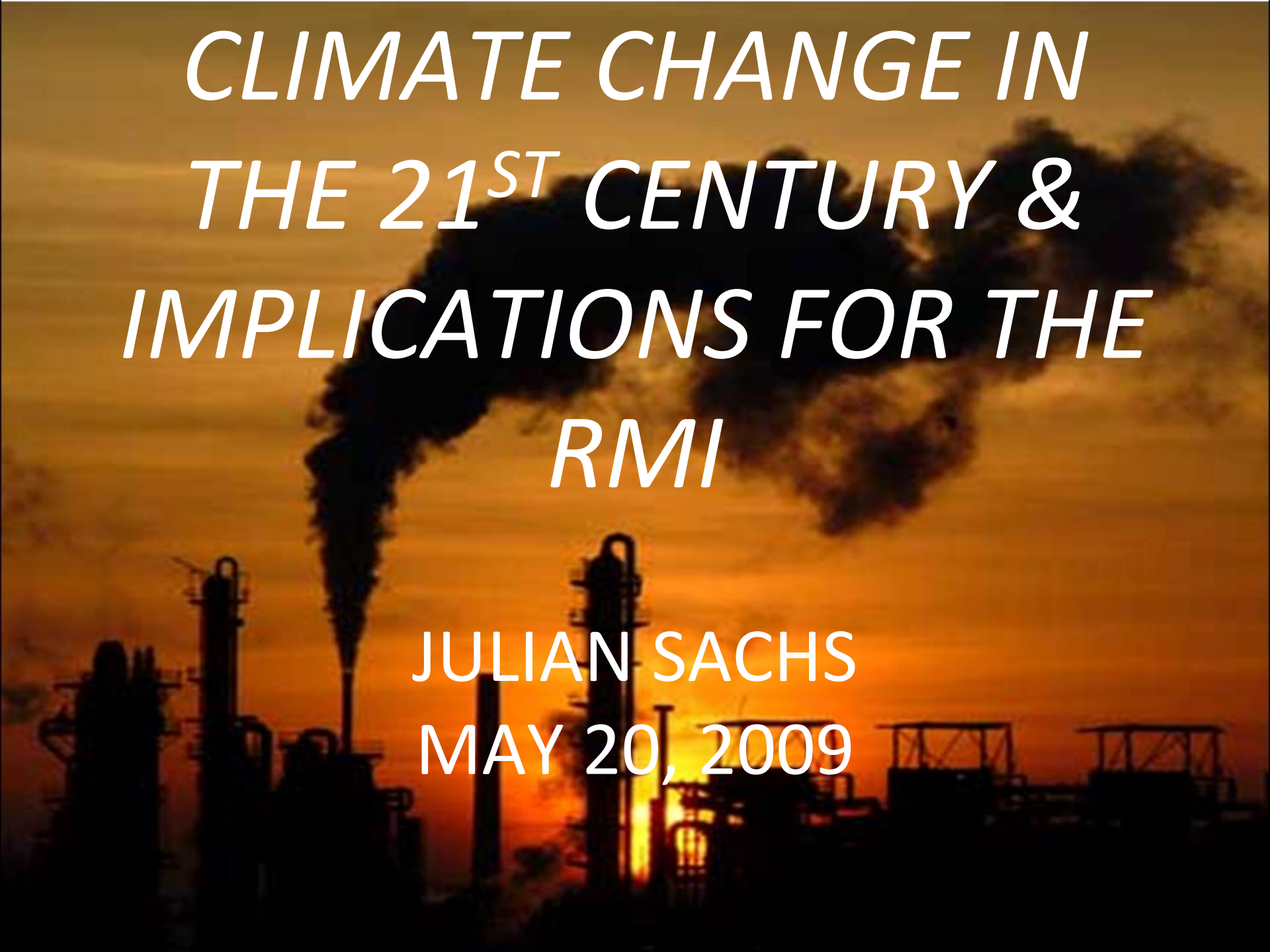
•Listed as a vulnerable by the International Union for Conservation of Nature and Natural Resources due to extensive collecting for food, aquaculture, and the aquarium trade

•Large populations in the Marshall Islands

http://www.nps.edu/News/ReadNews.aspx?id=3708&role=pao&area=media



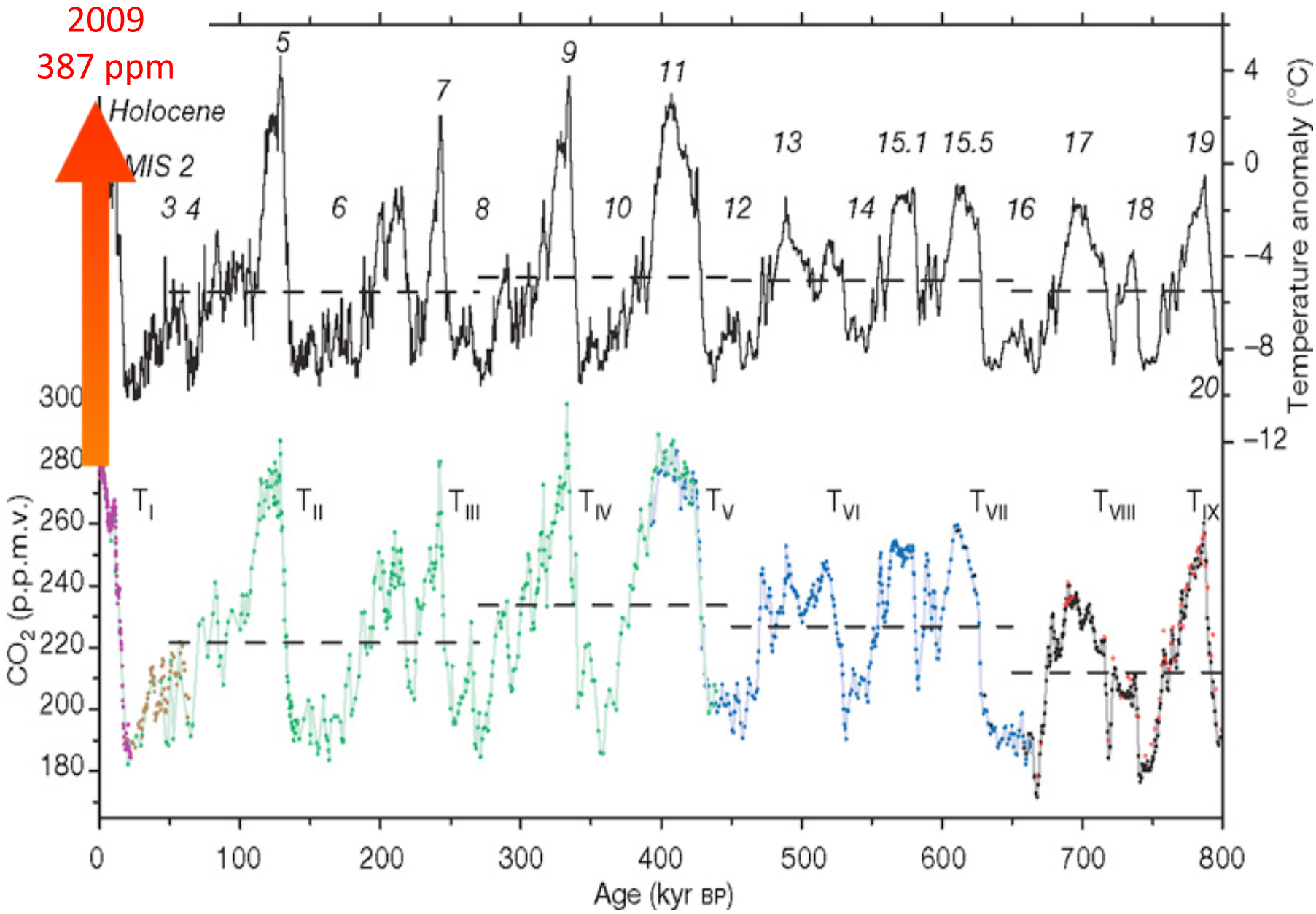


CLIMATE CHANGE IN THE 21ST CENTURY & IMPLICATIONS FOR THE RMI

JULIAN SACHS

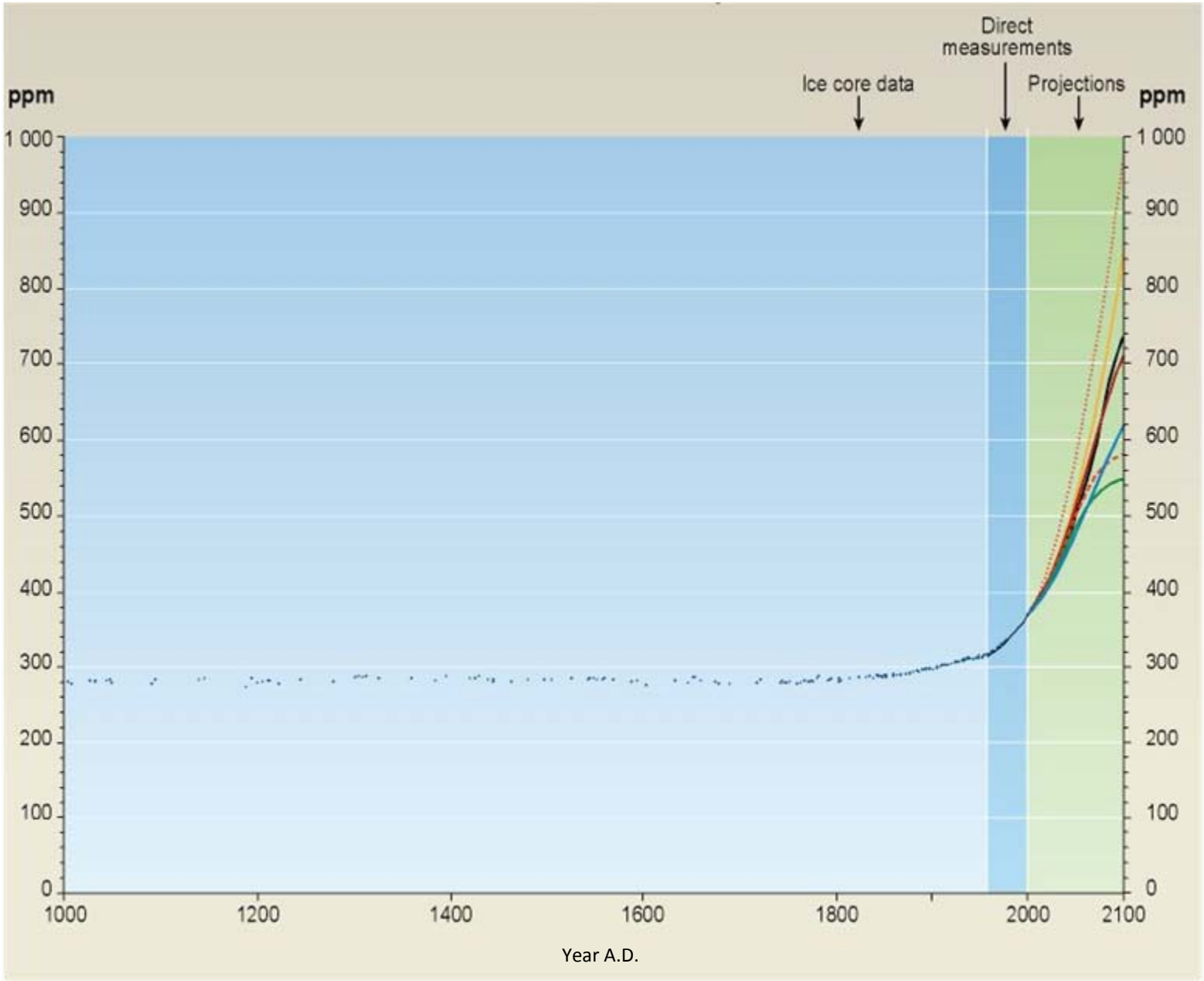
MAY 20, 2009

The Long View: CO_2 During the Last 800,000 Years



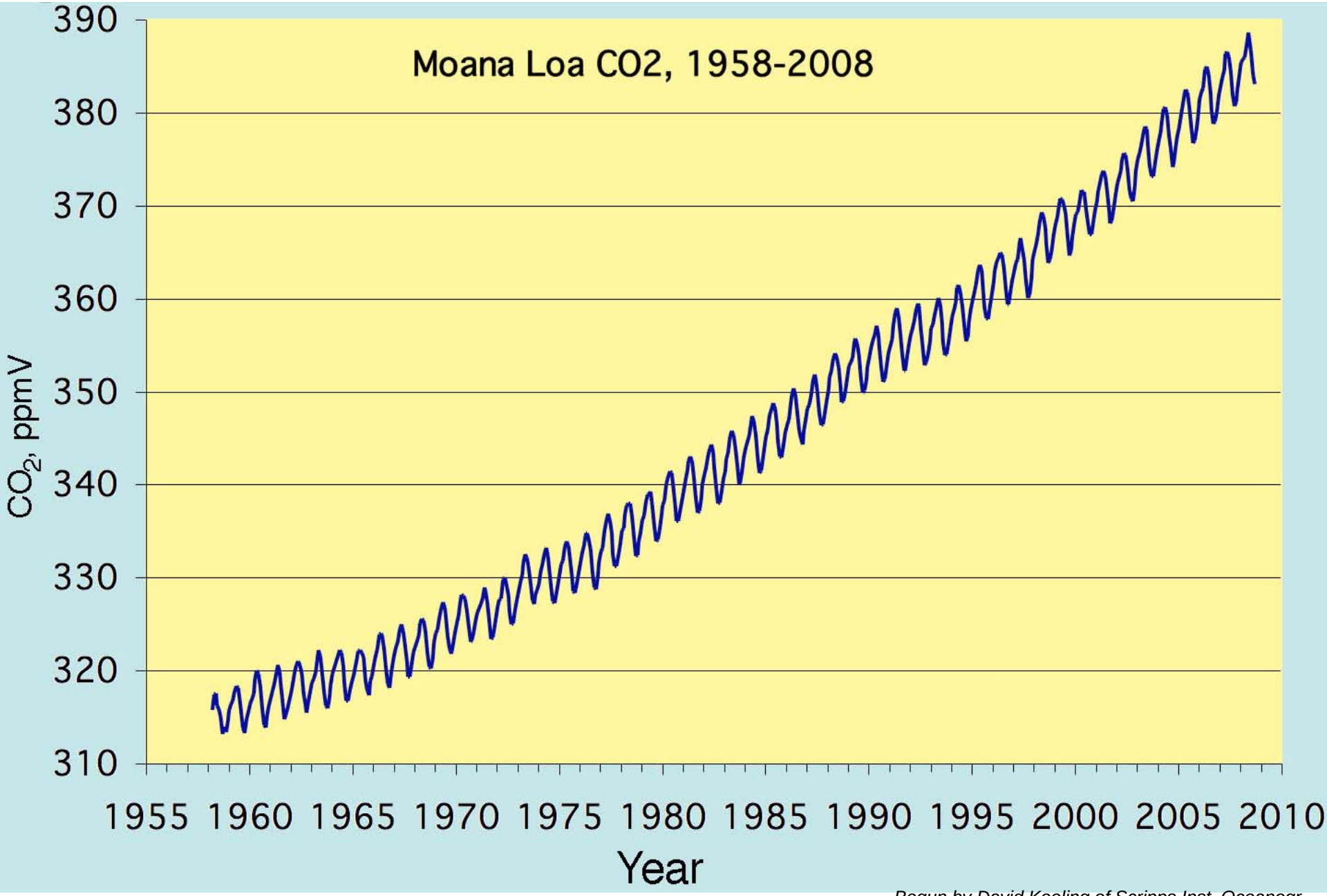
Luthi et al. (2008) *Nature* Vol. 453: 379-382

CO_2 for the last 1000 Years



IPCC 2001

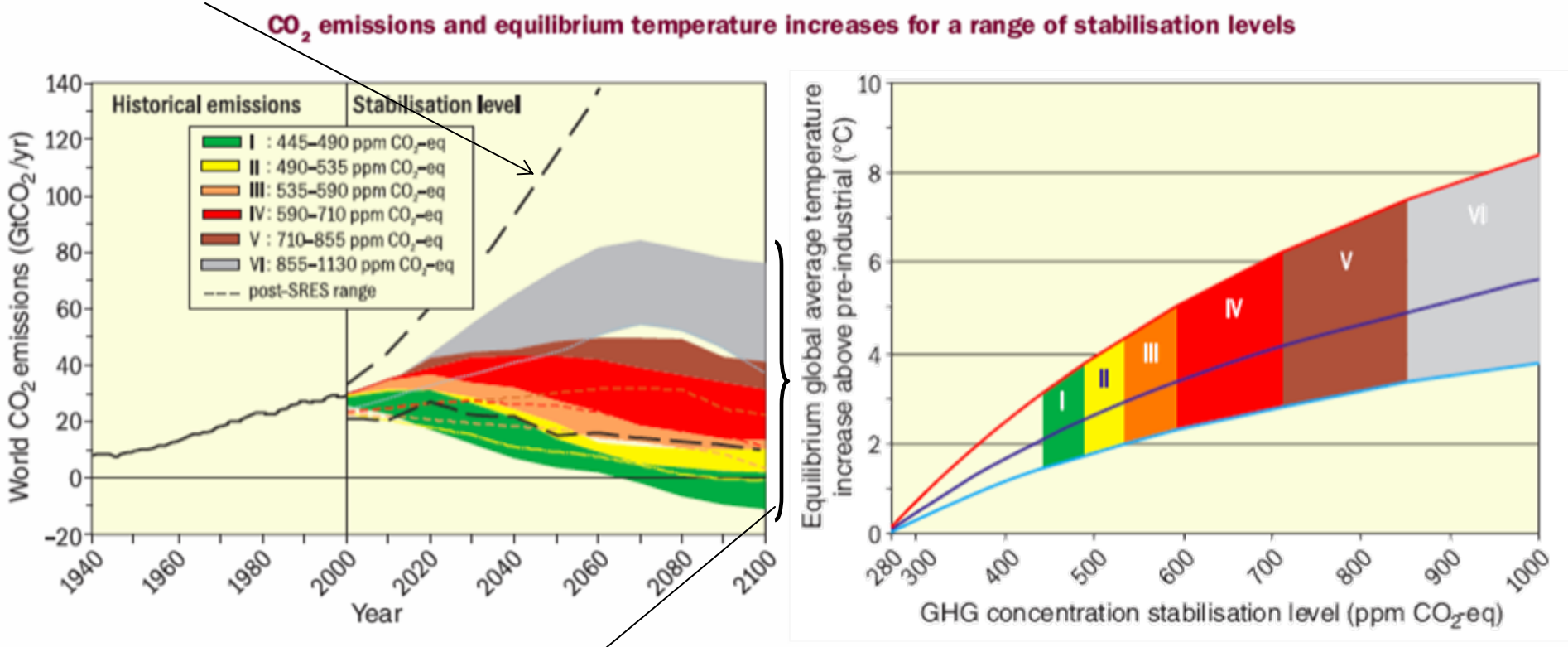
Direct Measurements of CO_2 in the Atmosphere Since 1958



Begun by David Keeling of Scripps Inst. Oceanogr.

Projected CO_2 Emissions to 2100 A.D.

- 2000-2006 trend

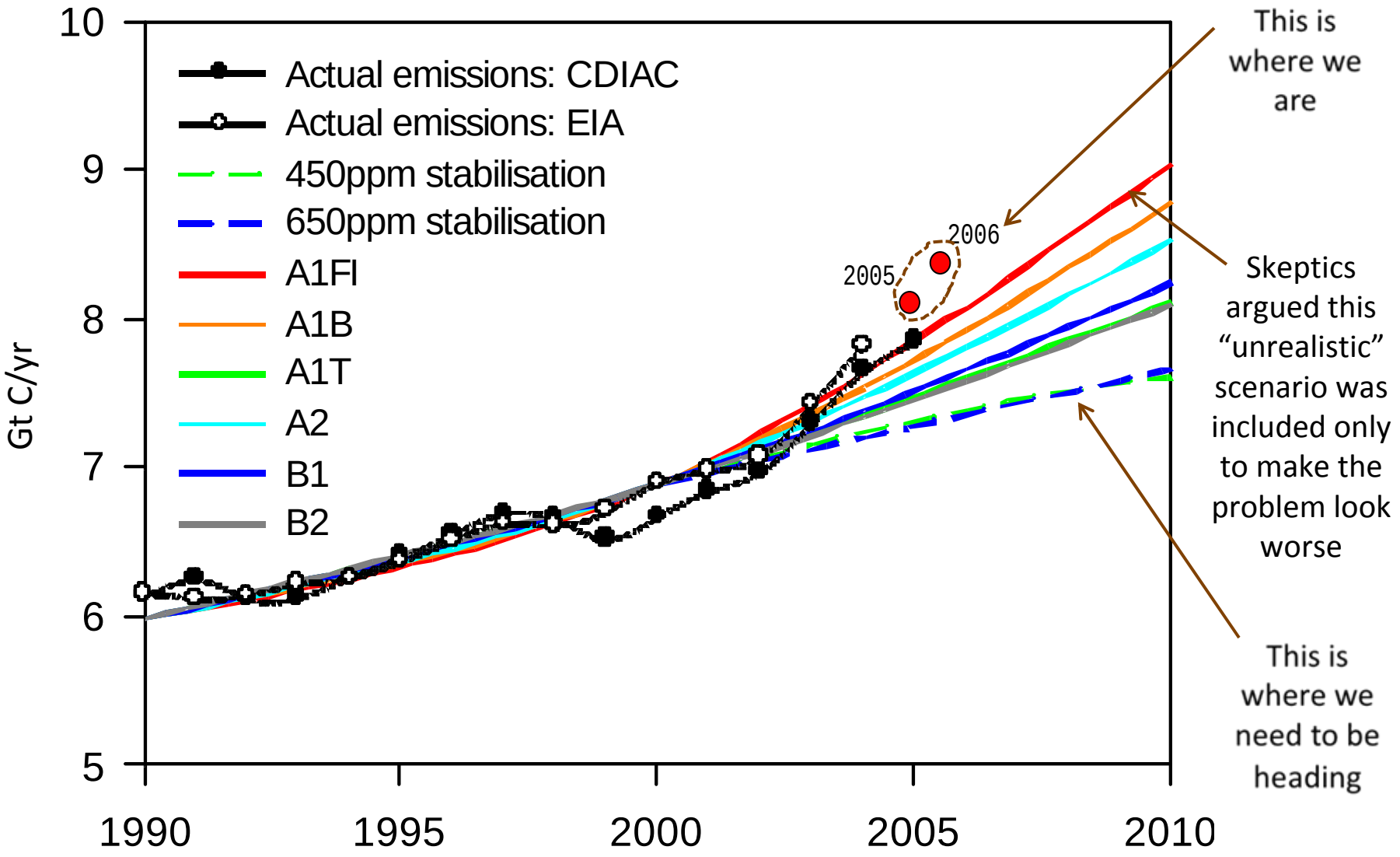


- Where emissions need to be in order to reach different target levels of atmospheric CO2, ranging from 445-1130 ppmV (comp. to 387 ppmV in 2008)

- Estimated global mean T change for the different emission scenarios
- Results for climate sensitivities of 3°C (dk. blue line), 2°C (lt. blue line), 4.5°C (red line) for CO_2 doubling

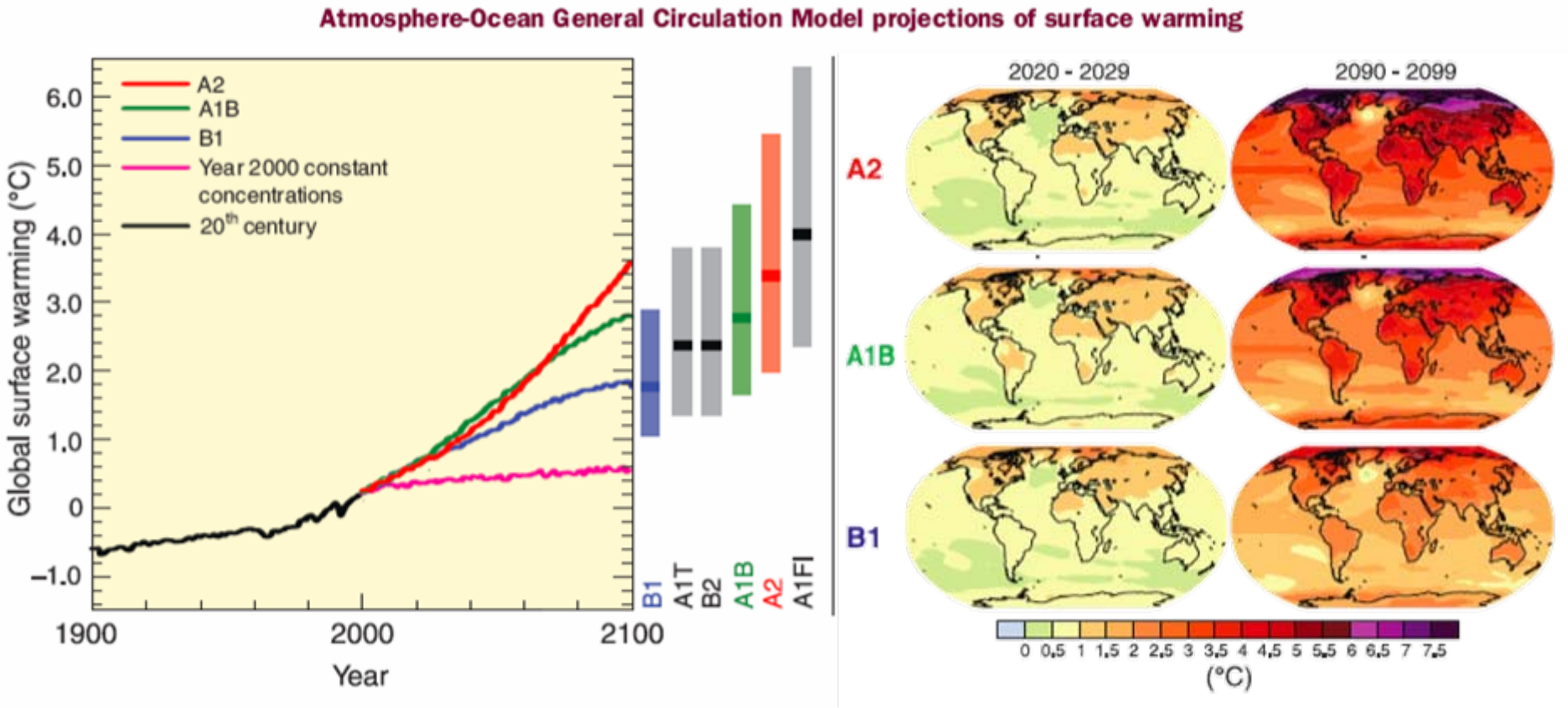
IPCC 2007 Synth. Rept. Fig. 5.1

Emissions are Rising Faster than Expected



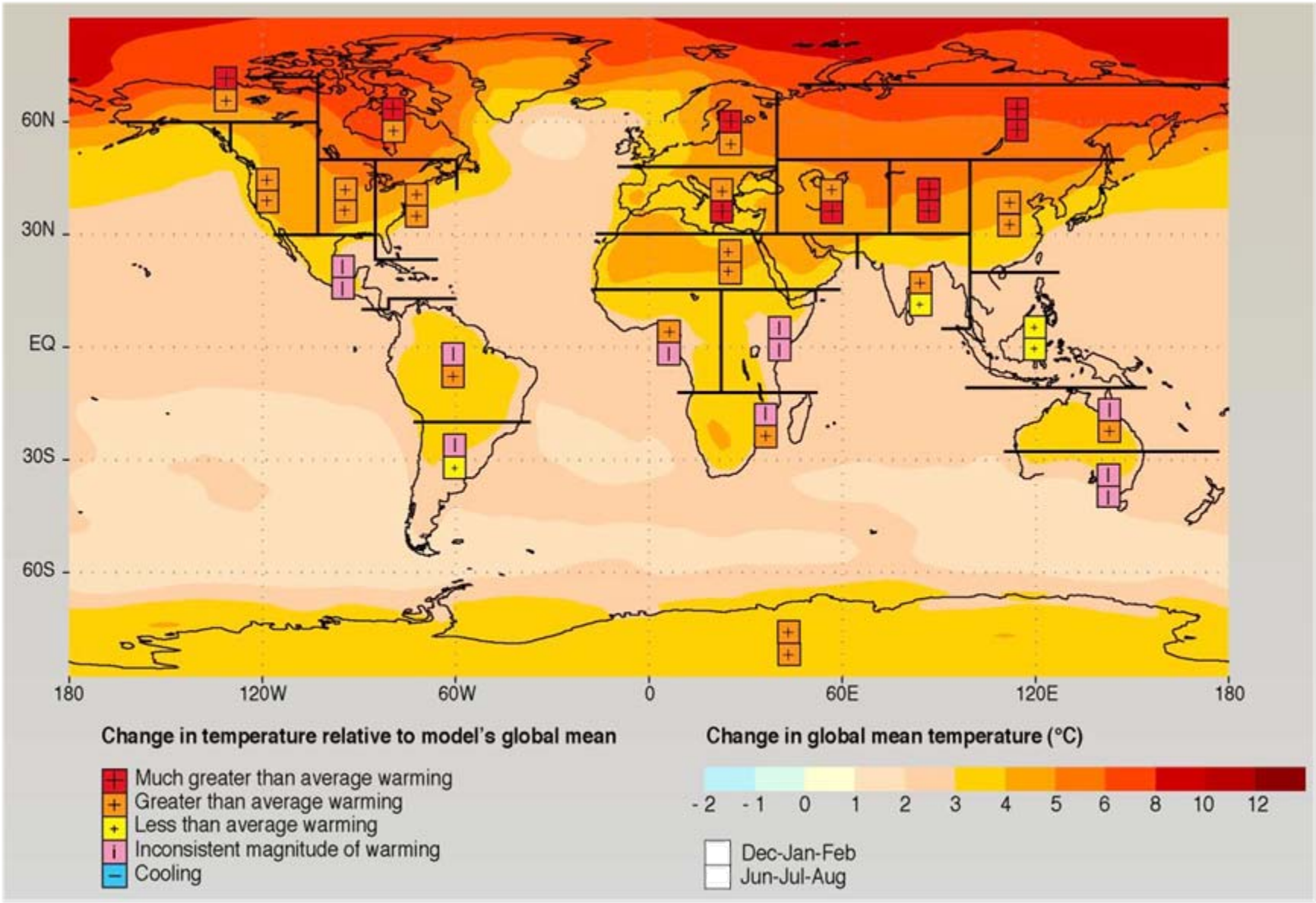
Raupach et al. 2007, PNAS; Canadell et al. (2007) http://www.globalcarbonproject.org/index.htm

Global Temperatures: 1900-2100 A.D.



IPCC 2007 Synth. Rept. Fig. 3.2

Expected Warming in 2100 A.D.



IPCC 2001

Ocean Acidification

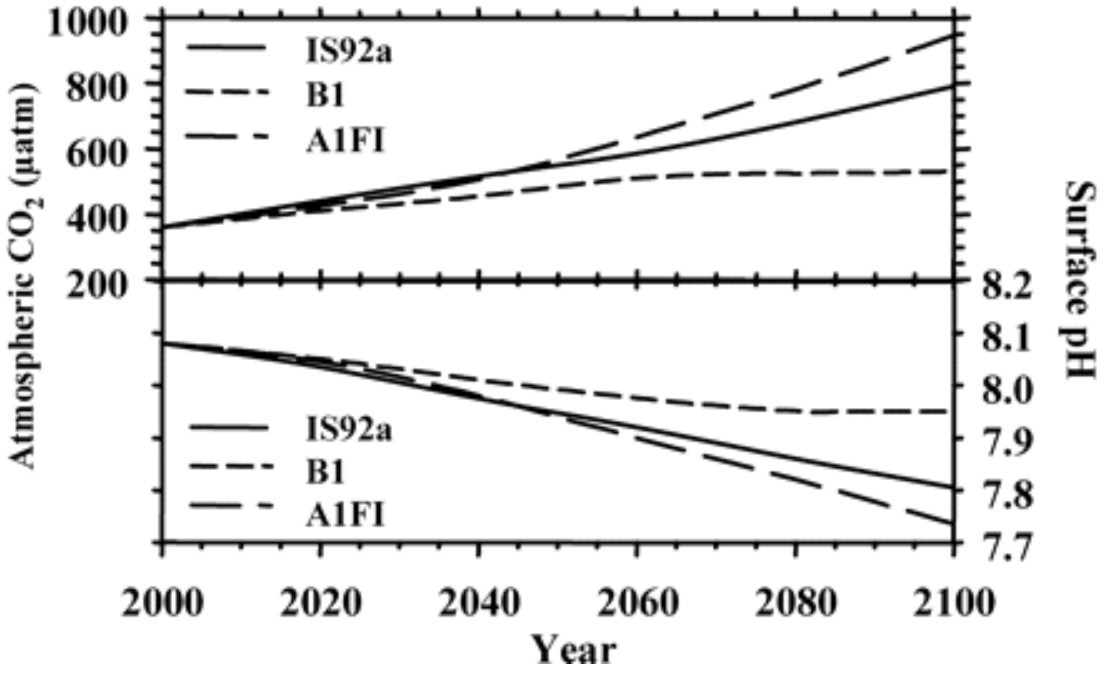
$$CO_2 + H_2O = H_2CO_3$$

Carbon Dioxide + Water = Carbonic Acid

$$H_2CO_3 + CaCO_3 = Ca^{2+} + CO_3^{2-} + H_2O$$

Carbonic Acid + Calcium Carbonate = Dissolved Shells

Ocean Acidification

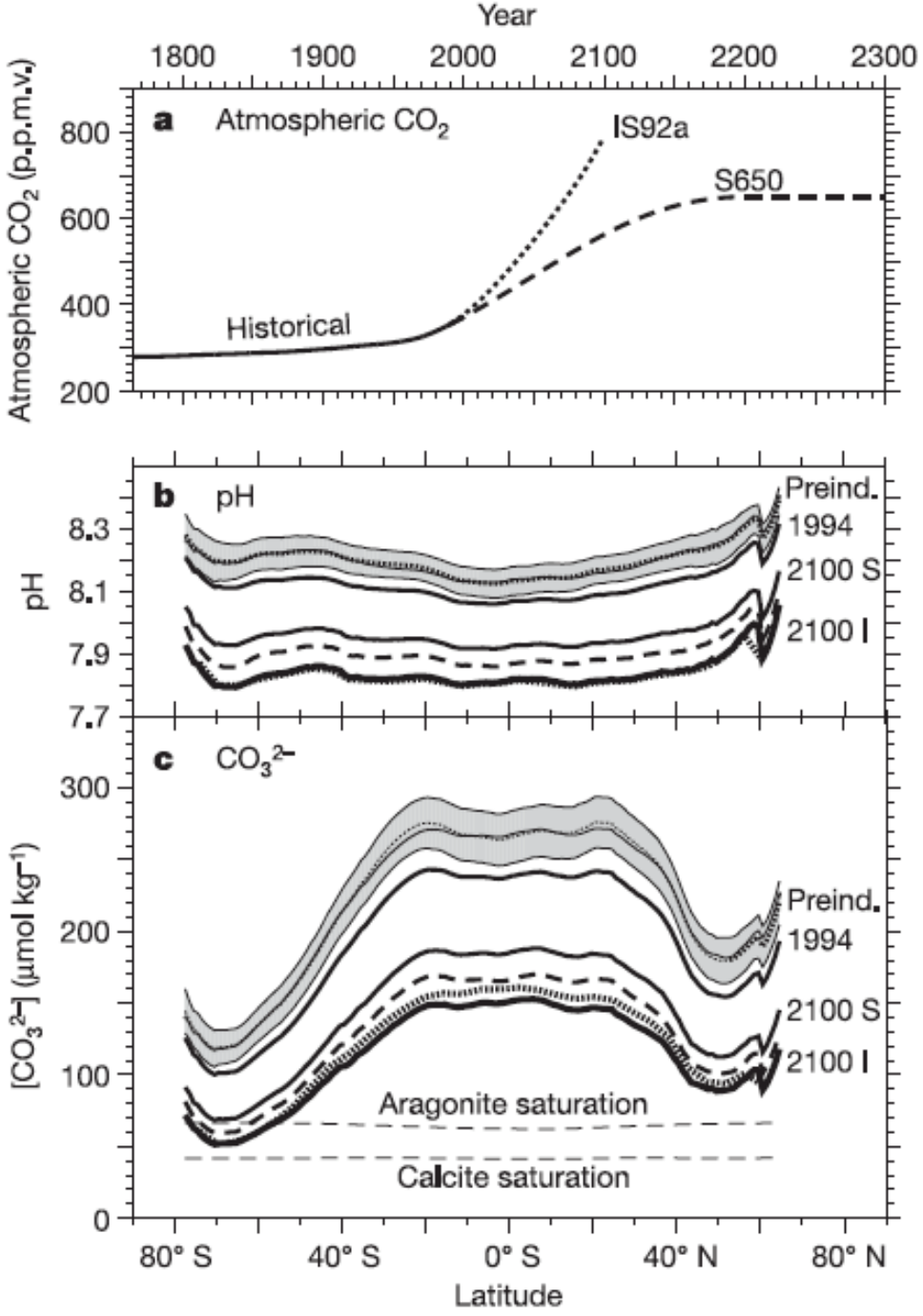


- Rising CO_2 levels this century…

…will acidify the surface ocean…

…making it difficult for calcifying organisms (corals, plankton, mollusks) to grow.

Fabry et al. (2008) *ICES Journal of Marine Science* Vol. 65(3):414-432.



Effect of Increased CO_2 on Ocean Acidity & $CaCO_3$ Saturation State 2000-2100 A.D.

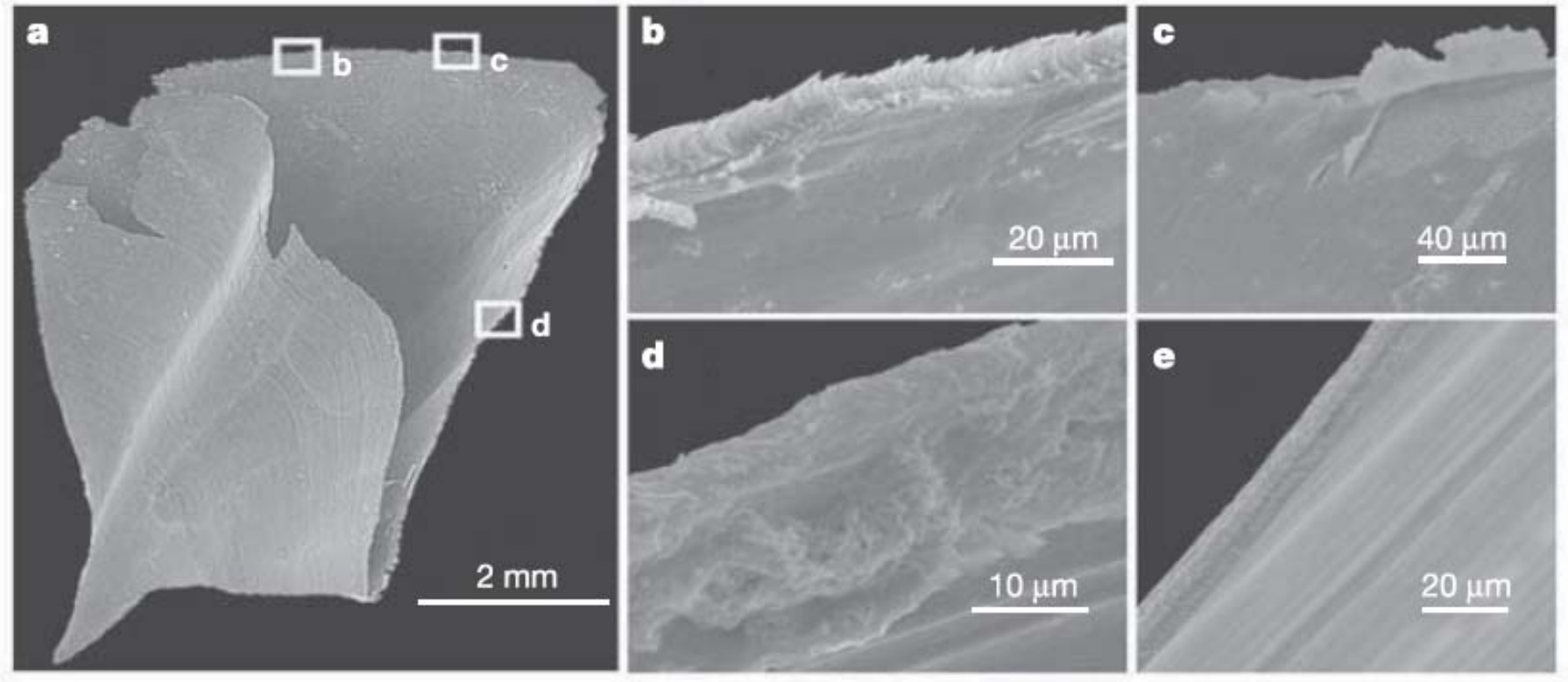
By 2100 A.D.

- pH of surface ocean drops 0.4 pH units
- CO_3^{2-} concentration in high S latitudes drops below saturation state for aragonite & approaches that for calcite
- $CaCO_3$-bearing biota unable to survive (e.g., coccolithophorids, pteropods)

Orr et al. (2005) *Nature* Vol. 437: 681-686.

Effects of Ocean Acidifcation on Pelagic Ecosystems

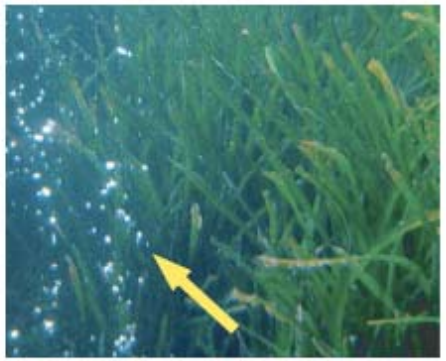
- Pacific Ocean pteropod (*C. pyramidata*, c) rapidly dissolves in water undersaturated with respect to aragonite (b-d). Unexposed shell in (e).



Orr et al. (2005) *Nature* Vol. 437: 681-686.

Effects of Ocean Acidifcation on Benthic Ecosystems

Posidonia oceanica with heavy overgrowth of Corallinaceae at pH 8.2

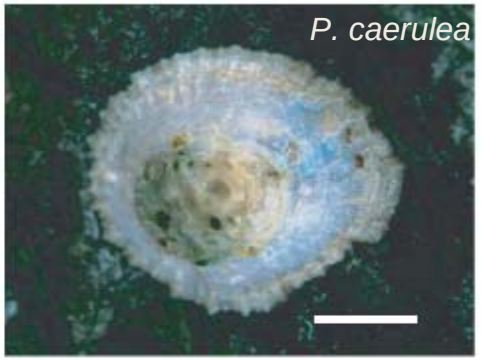


… lacking Corallinaceae at pH 7.6

O. turbinata with intact periostracum at pH 8.2

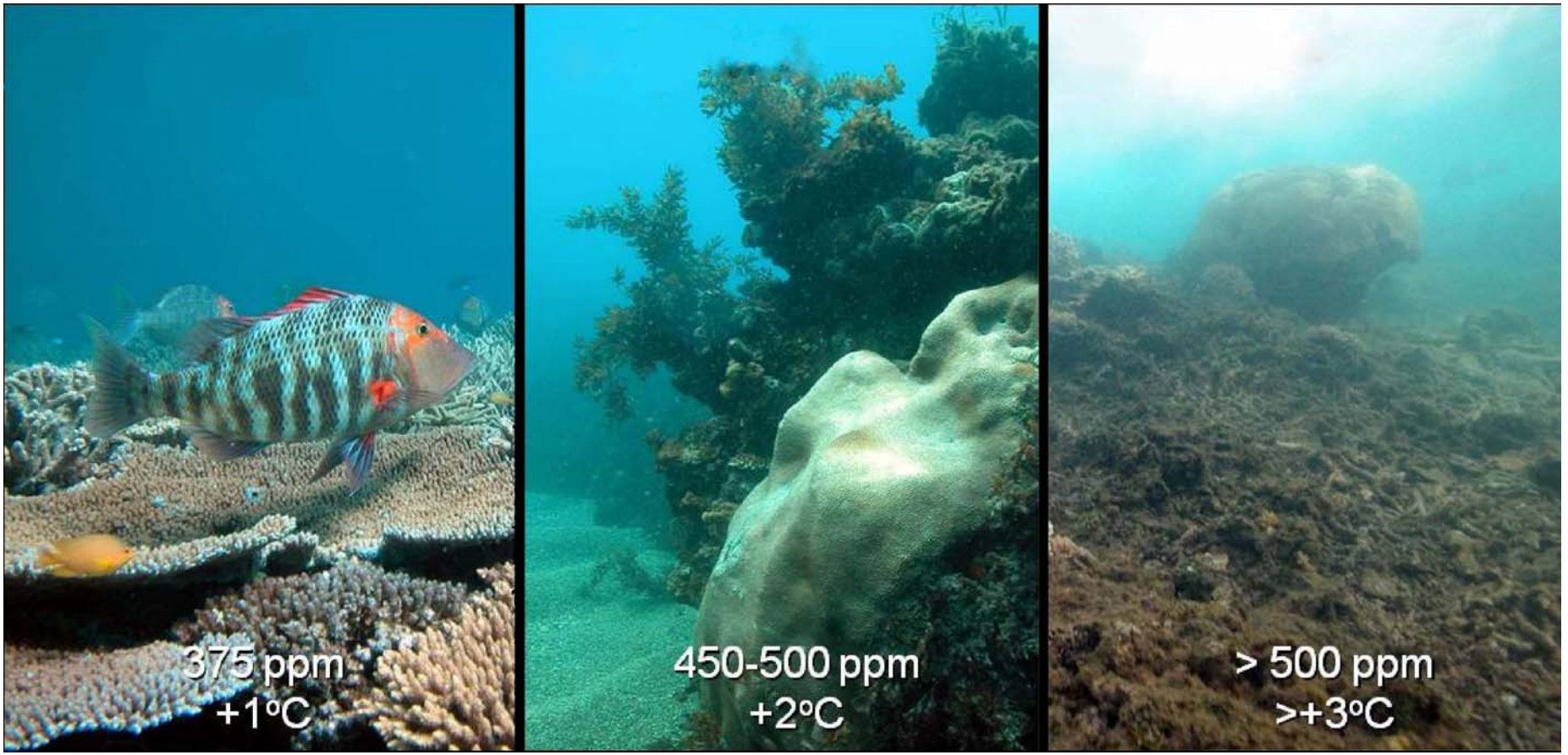
… periostracum partly removed at pH 7.3

Severely eroded & pitted shells at pH 7.4



Hall-Spencer et al. (2008) *Nature* Vol. 454: 96-99.

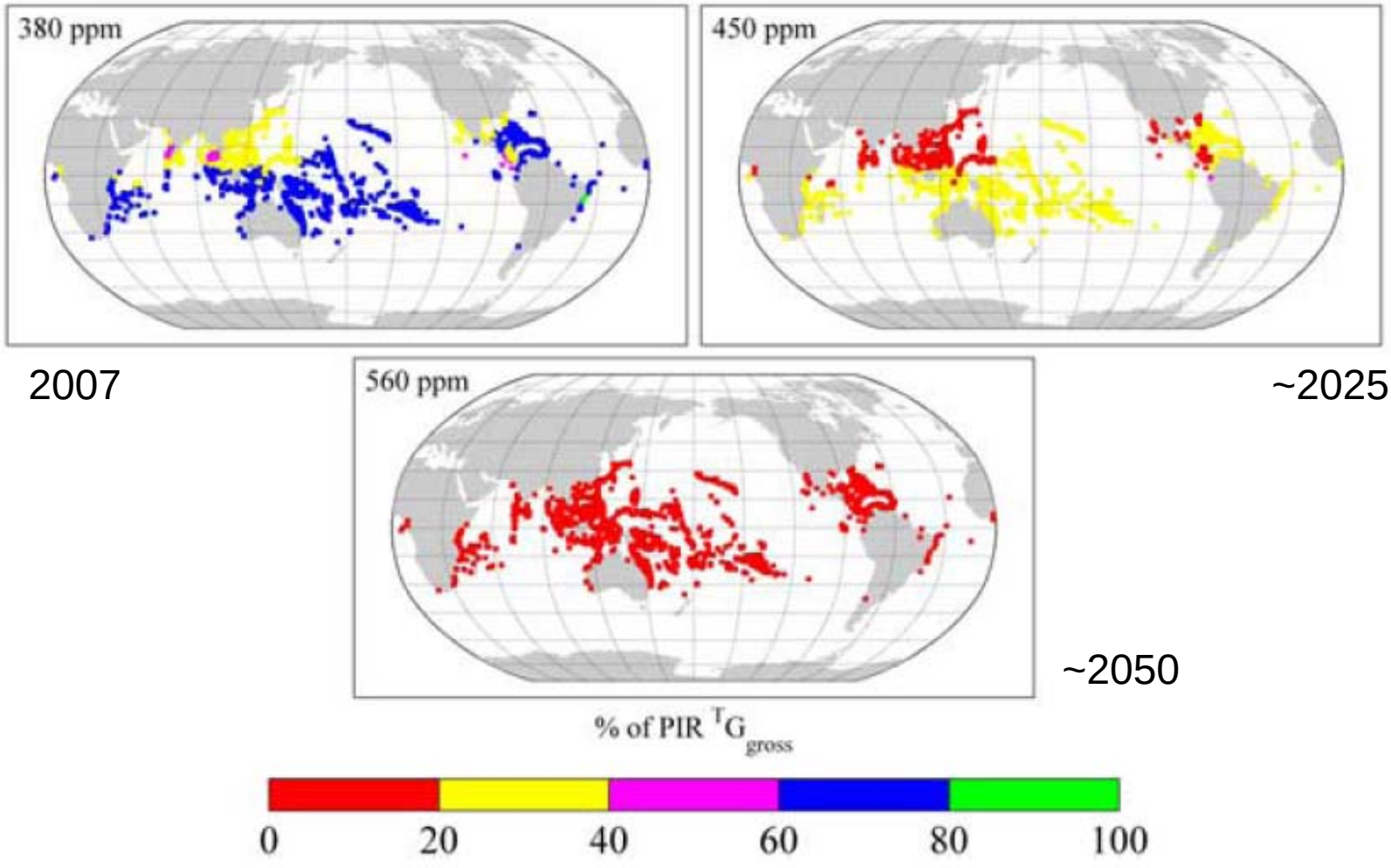
Effects of Ocean Acidification on Coral Reefs



2006 A.D. … in 10 years … in 30 years

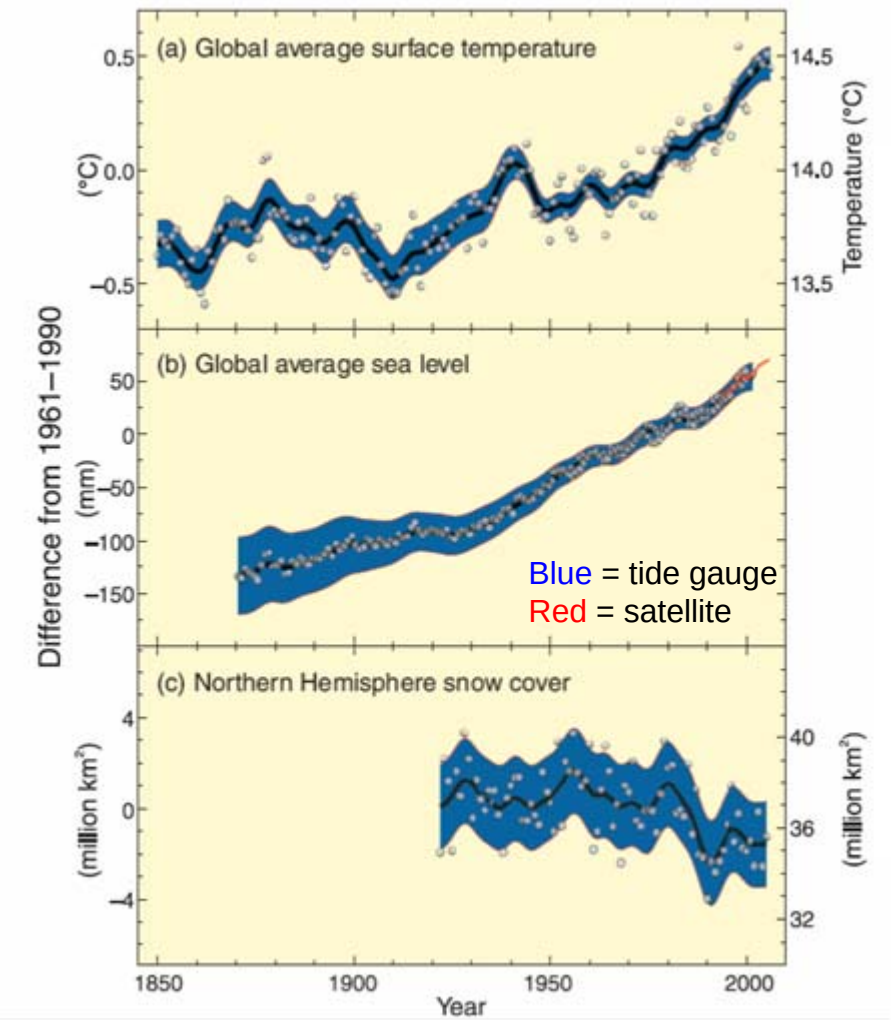
http://www.noaanews.noaa.gov/stories2007/images/co2coral2.jpg

Projected Decline in Coral Growth for Different CO_2 levels (rel. to pre-industrial 280 ppm)



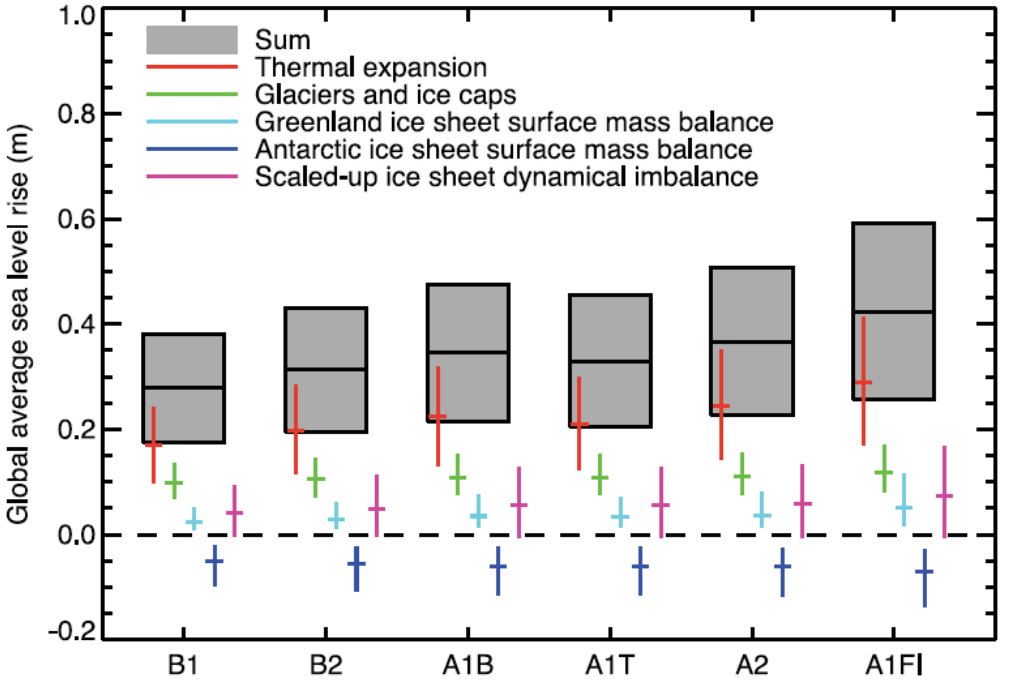
Silverman et al. (2009) *Geophys. Res. Lett.,* Vol. 36, L05606

Global Mean Sea Level Rise



- Observations
- Recent: ca. 5 cm/decade

IPCC 2007 AR4 Synth. Rept. Fig. 1.1



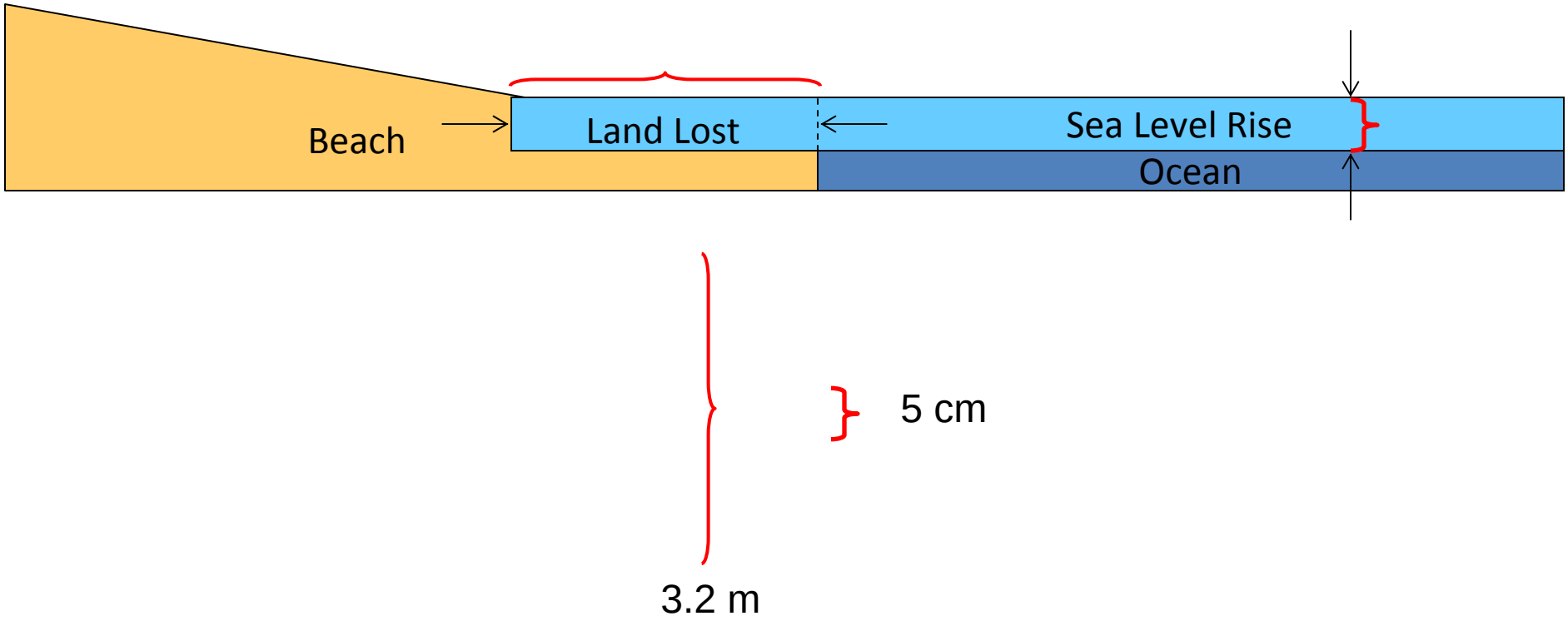
- Projections 2090-2099

(relative to 1980-1999)

- 20-60 cm or more

IPCC 2007 AR4 Chap. 10, Fig. 10.33

Exaggerated Loss of Land from Rising Sea



- A 5 cm sea level rise results in a 3.2 m loss of land in this example with a beach slope of 1:64 or 1.6%

Implications for the RMI

- Higher sea level will cause increased frequency of floods & make most of RMI uninhabitable before 2100 AD
- Acidification of seawater will likely devastate much of the coral reefs in RMI by 2050 AD
- Warmer ocean temperatures will increase the frequency and extent of coral disease such as bleaching over next few decades

Wrapup

- e-mail, phone or drop in to see any of us
- See you at Majuro airport on Sunday June 21st!