Coral reefs and climate change

Elizabeth Selig and John Bruno

Climate change and coral reefs

ECOLOGY

First Coral Species Listed as Threatened

Are U.S. Coral Reefs on the Slippery Slope to Slime?

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T. P. Hughes,[7] C. V. Kappel,[8] F. Micheli,[8] J. C. Ogden,[9] H. P. Possingham,[2] E. Sala[3]

Rising Ocean Temperatures Threaten Florida's Coral Reef

ENVIRONMENT

Scientists Warn of Coral Bleaching in Caribbean

Listen by Lourdes Garcia-Navarro

All Things Considered, March 14, 2006 · Scientists say that the biggest episode of coral-reef bleaching is taking place in the Caribbean. As much as 70 percent of reefs are suffering in some areas, and the issue is affecting the whole basin from the Florida Keys to Panama.

Warming set to 'devastate' coral

By Paul Rincon
BBC News science reporter

Rising ocean temperatures look set to cause lasting devastation to coral reef systems, a study suggests.

An international team of researchers looked at reefs in the Seychelles, where an ocean warming event in 1998 killed much of the live coral.

Dead reefs collapsed and became covered in algae

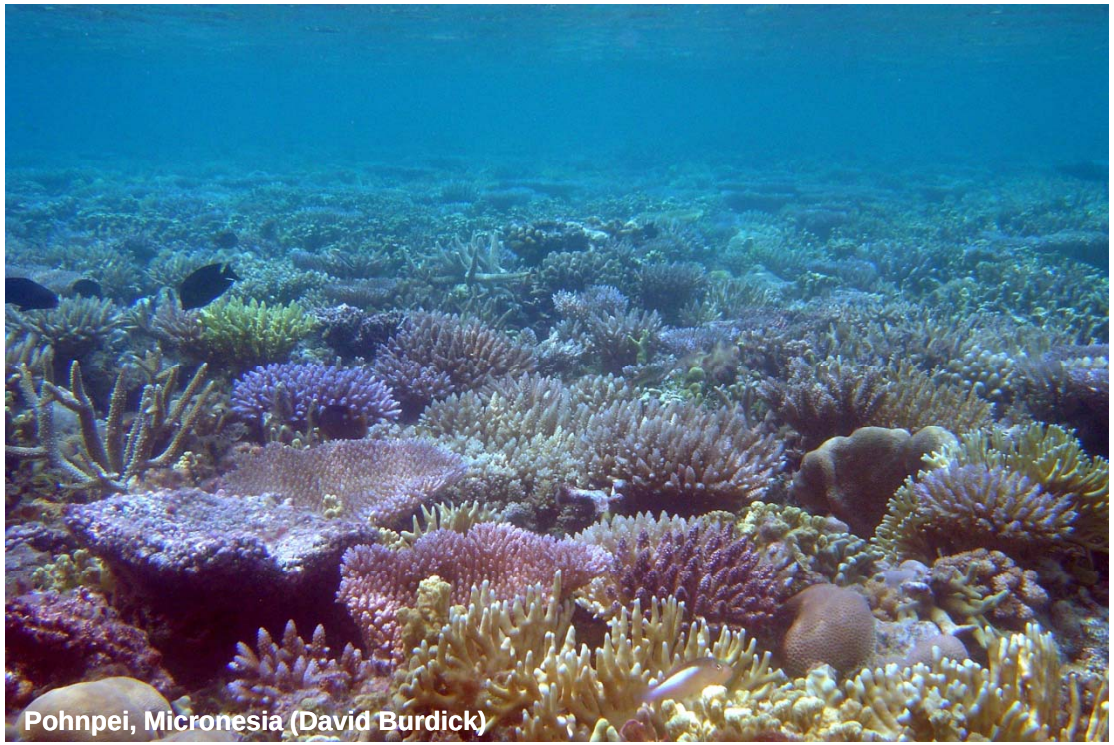
Lecture outline

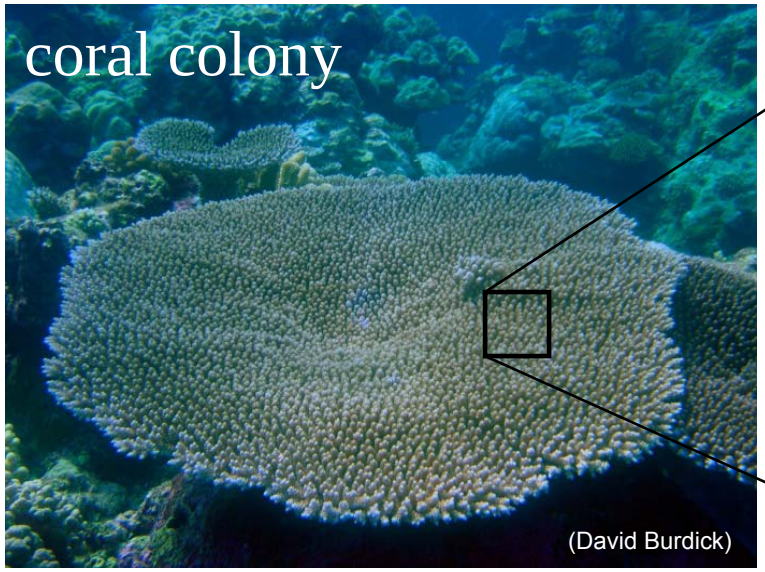
- Basic coral biology and terms
- Climate change effects on coral reefs
  - Range shifts
  - Ocean circulation changes
  - Sea level rise
  - Ocean acidification
  - Ocean temperature increases
    - bleaching
    - disease
- Coral Reef Temperature Anomaly Database (CoRTAD)

Great Barrier Reef (Robert Ricker)

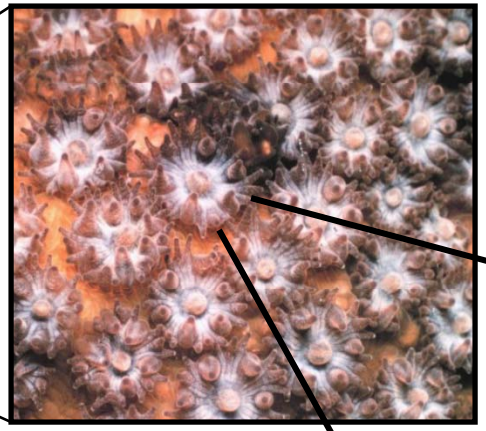
Basic coral biology: physical needs for survival of corals

- Light
- Low nutrient water
- Fairly narrow temperature range (21°C - 30°C)

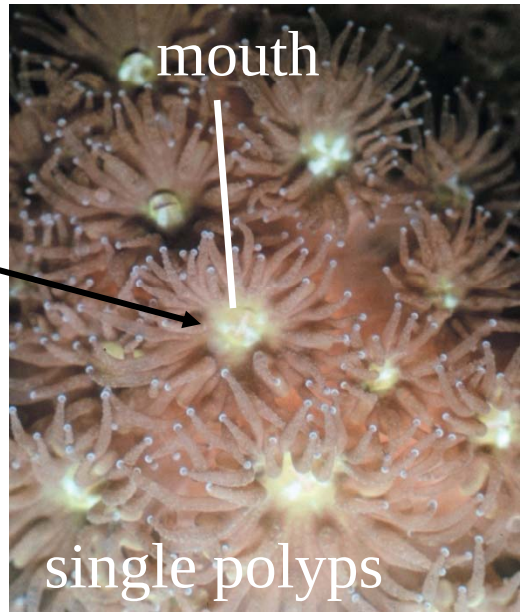




colonial coral polyps



(James P. McVey)



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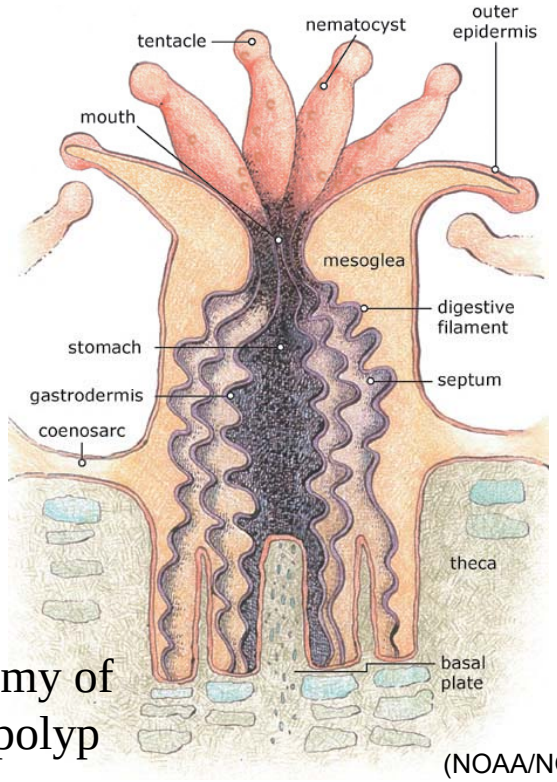
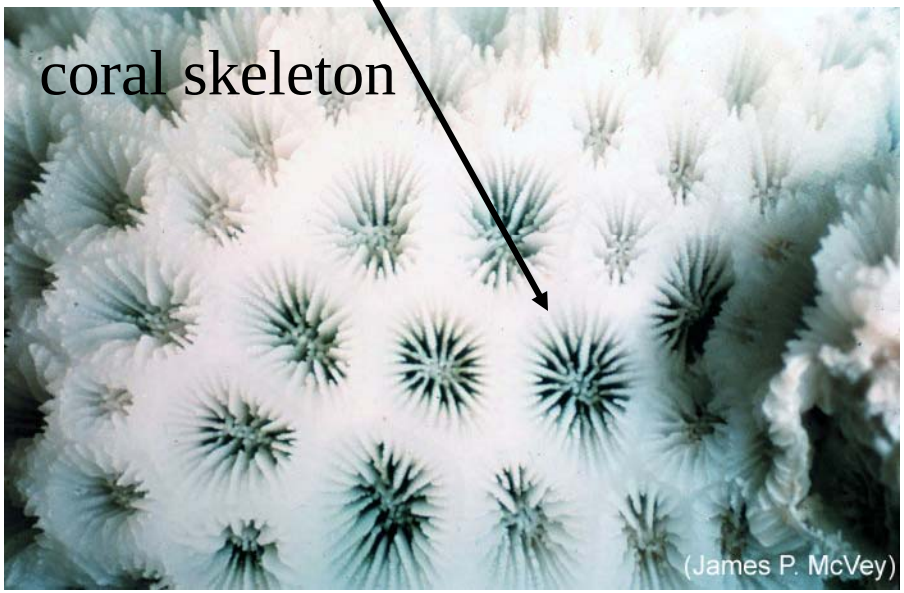


Anatomy of coral polyp

(NOAA/NOS)



Basic coral biology: coral-algal symbiosis

Benefits to coral:
1) productivity
2) calcification
3) nutrient recycling
4) provision of O_2

Benefits to zooxanthellae:
1) protection from predators
2) regulation of environment
3) nutrient recycling
4) provision of CO_2

Coral tissue with zooxanthellae

Coral stress response: coral bleaching

- What is it?
  - A stress response to unfavorable environmental conditions
  - Loss of algal pigments or zooxanthellae expulsion or both
- Causes:
  - Change in ocean temperature (+ / -)
  - Increase in visible light or UV light
  - Decreased salinity
  - Synergism of many stressors

Coral stress response: coral bleaching

Coral head bleaching (left) and recovery (right)

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    - bleaching

    - disease
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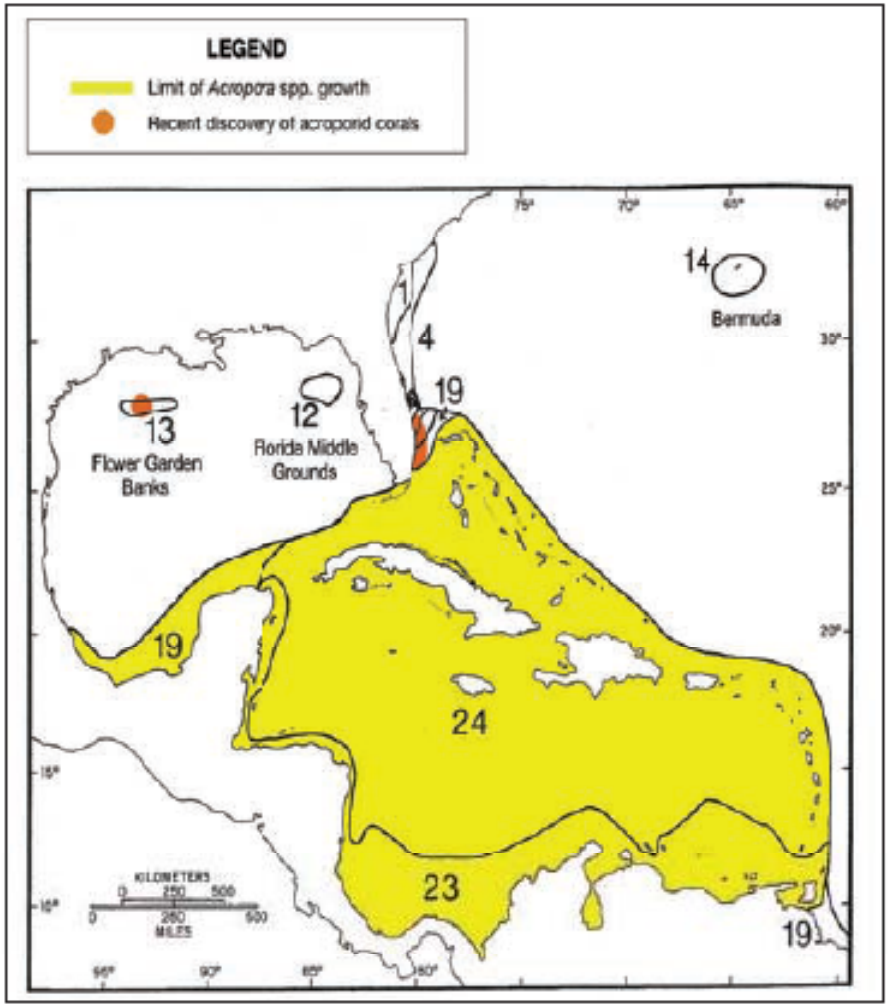
Great Barrier Reef (Robert Ricker)

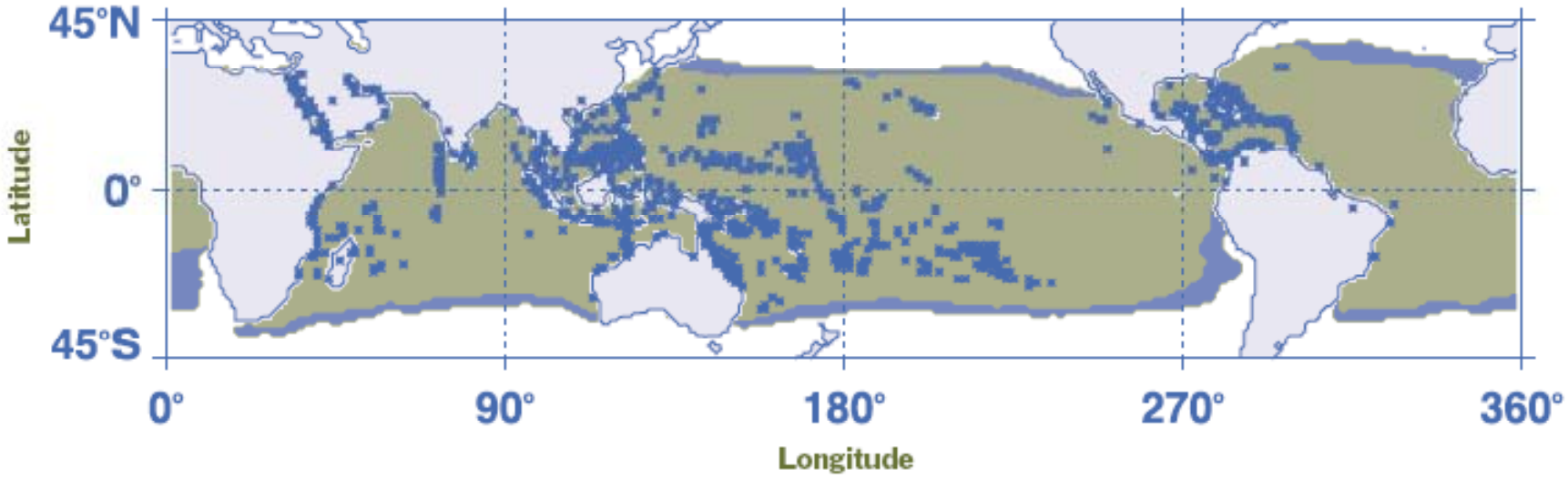
Range shifts



(Image: Precht and Aronson, 2004)

(Photo: John Bruno)

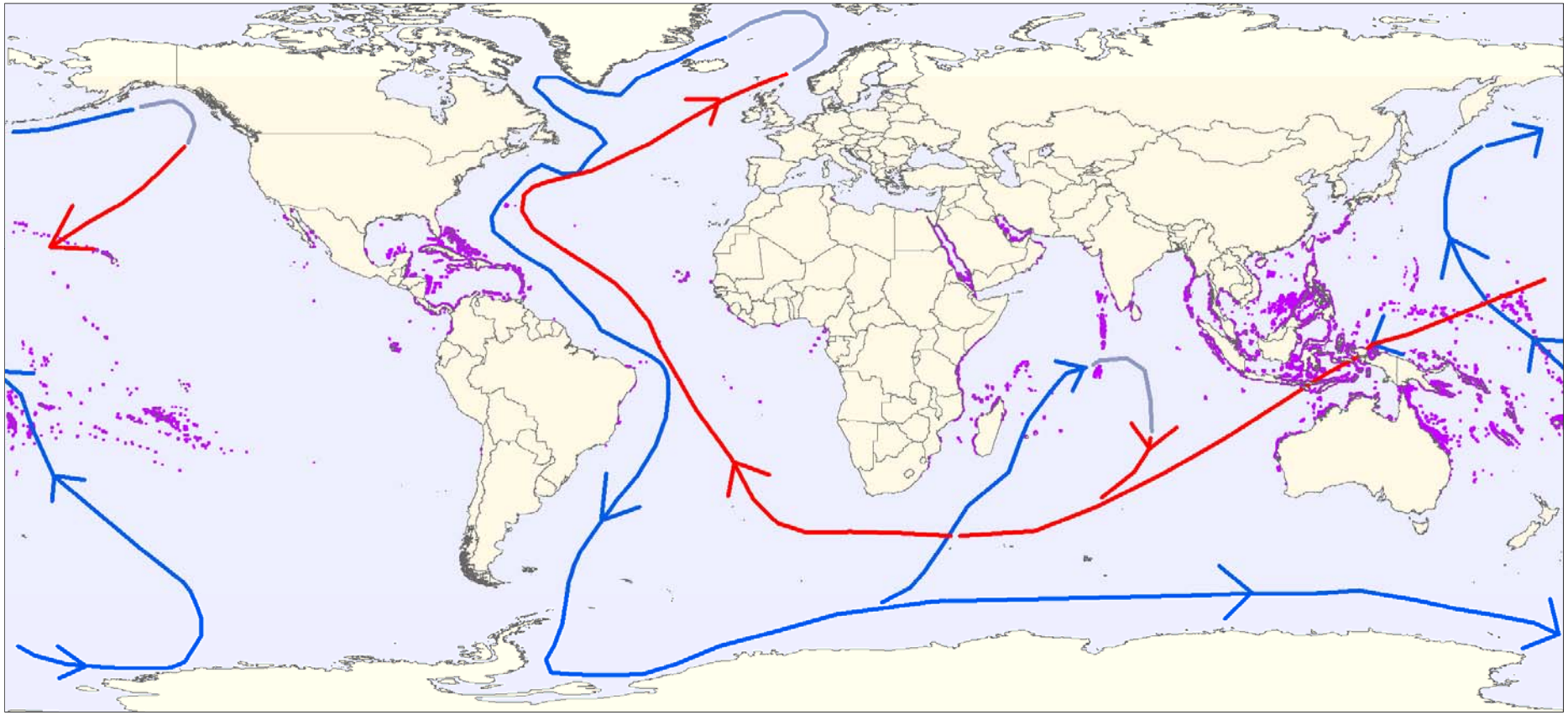
Range shifts



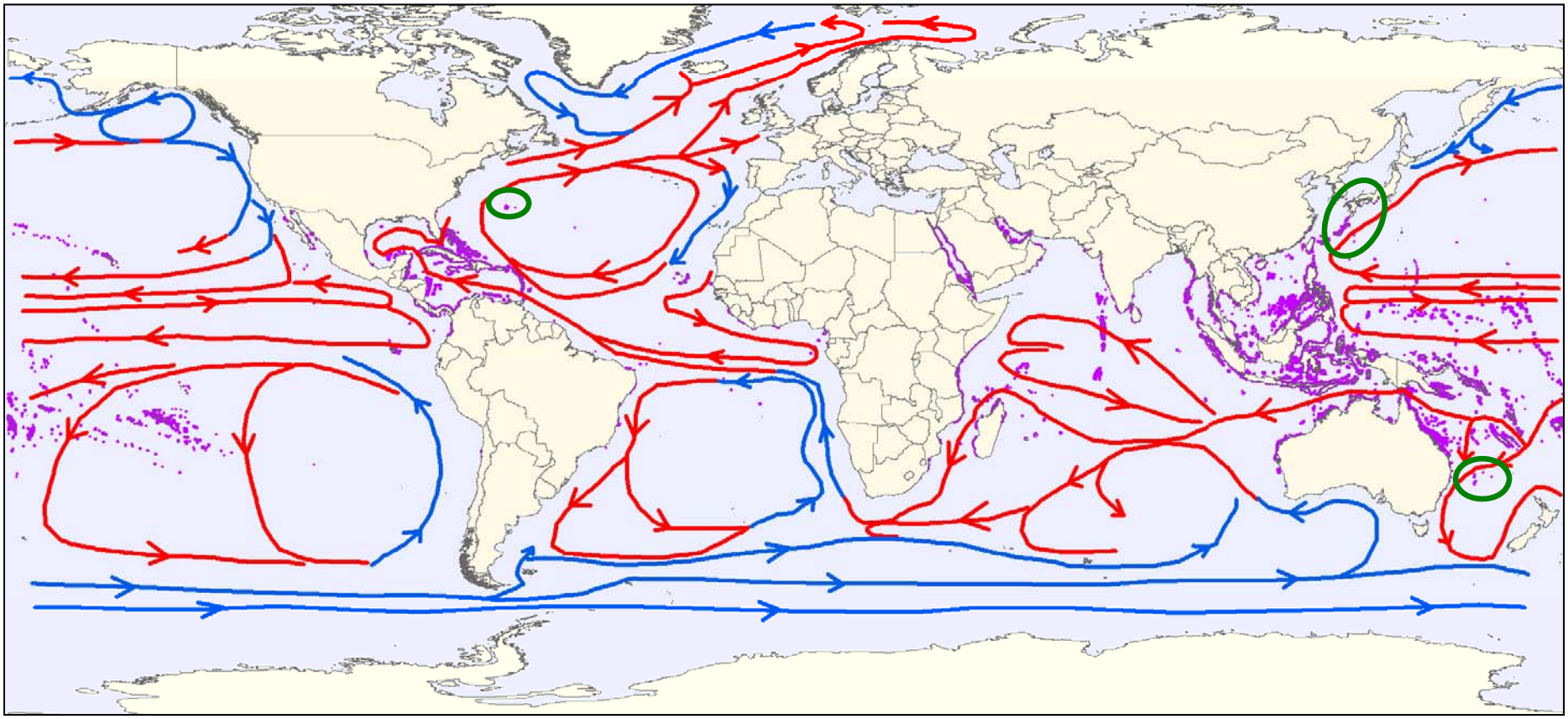
Net gain in reef habitat area: very minor

Buddemeier et al, 2004

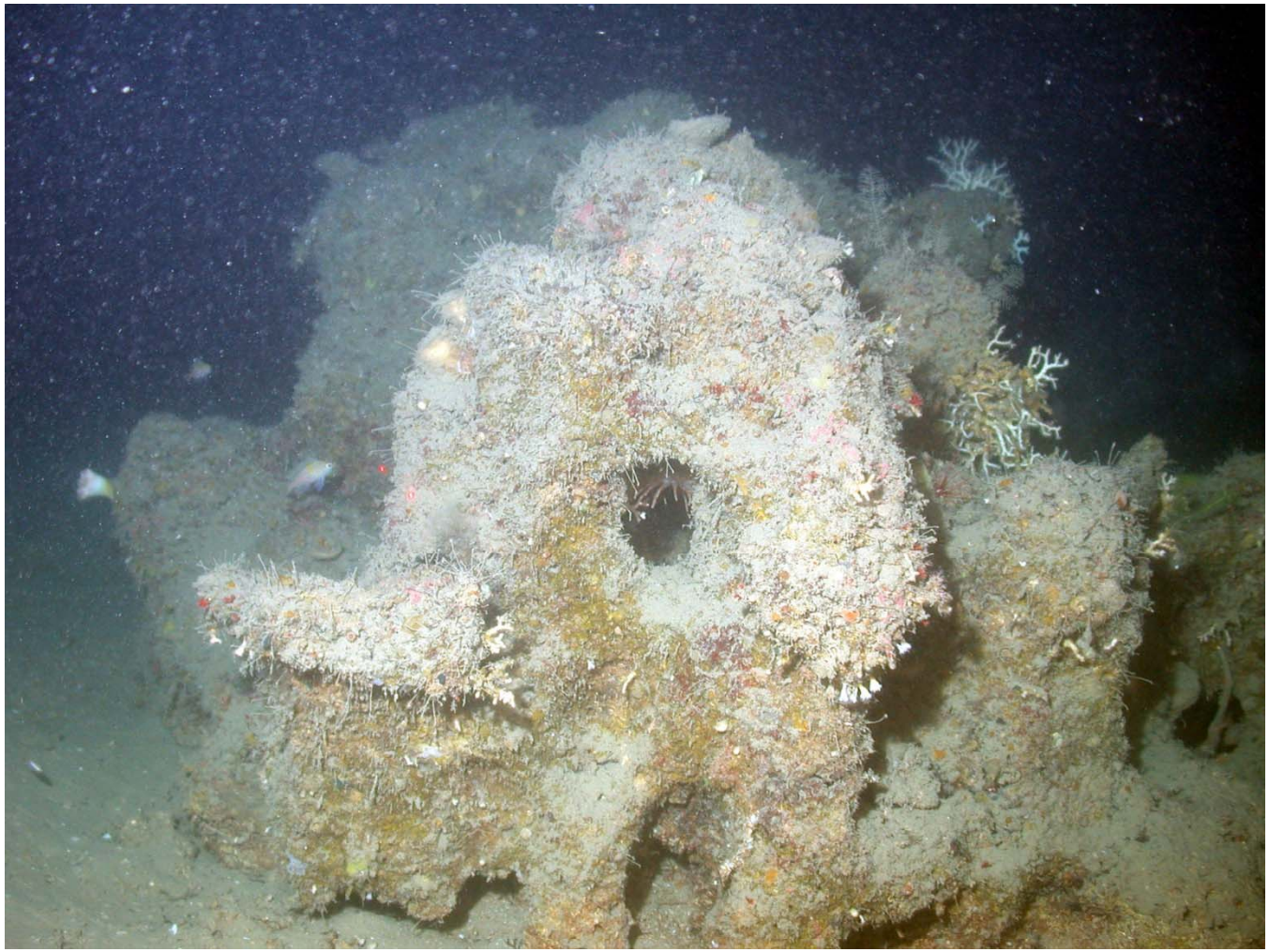
Ocean circulation changes



Ocean circulation changes



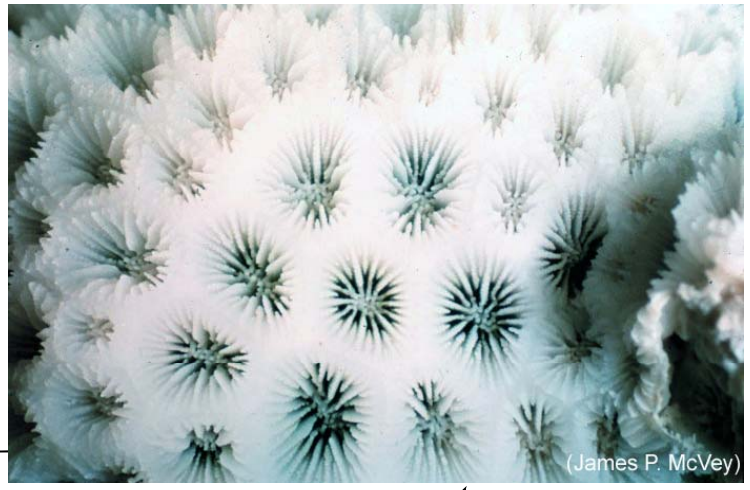
Sea level rise



Remnants of a drowned reef below the photic zone on West Bank, Flower Garden Banks National Marine Sanctuary, Gulf of Mexico
(NURC/UNCW and NOAA/FGBNMS)

Ocean acidification

CO_2



$CO_{2\,(aq)} + H_2O \leftrightarrow H_2CO_3$

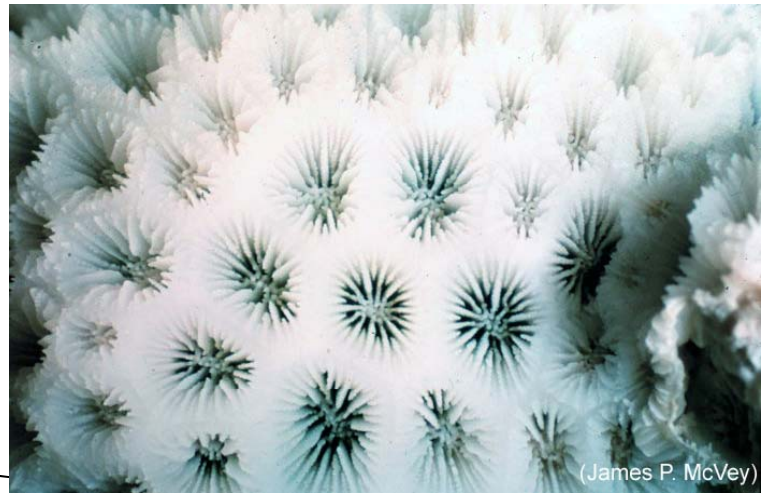
$H_2CO_3 \leftrightarrow H^+ + HCO_3^-$

$HCO_3^- \leftrightarrow H^+ + CO_3^{2-}$

$CaCO_3$

Ocean acidification

CO_2



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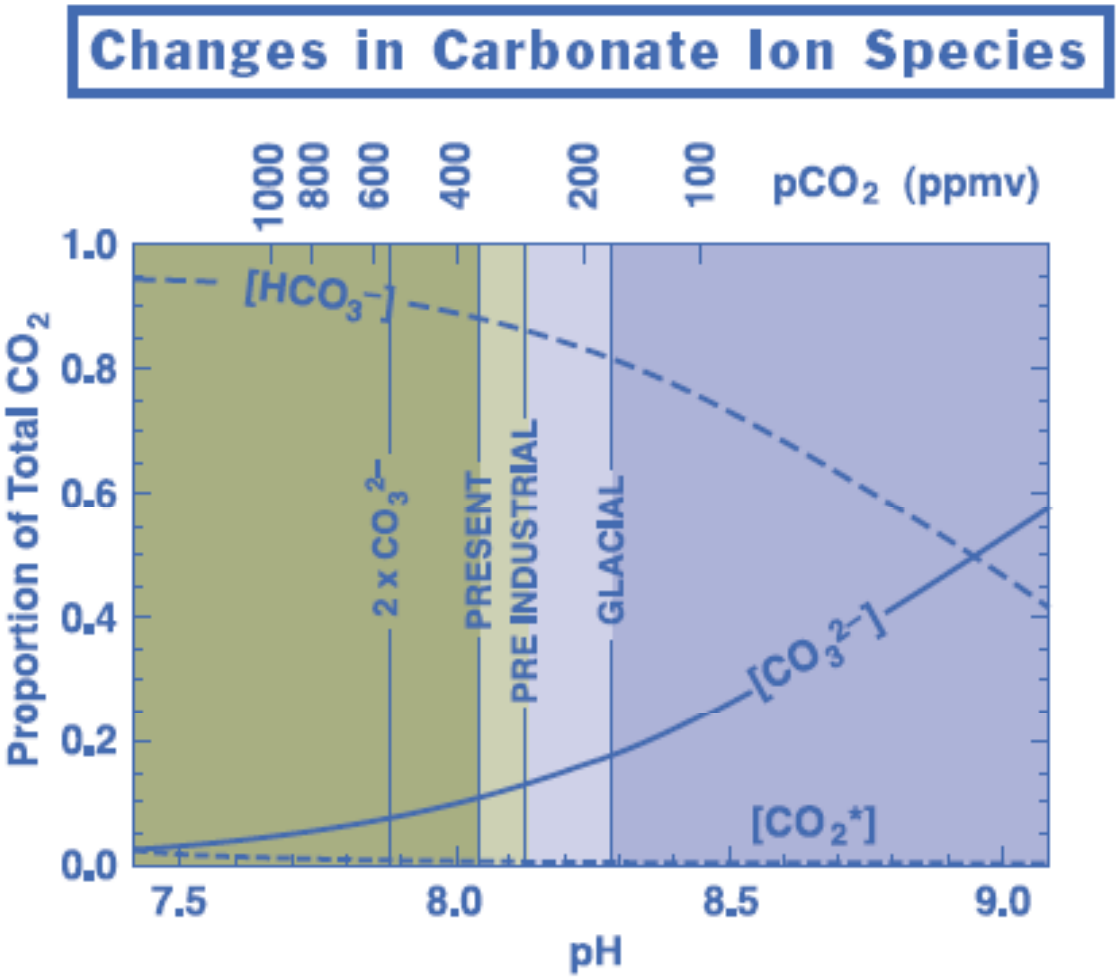
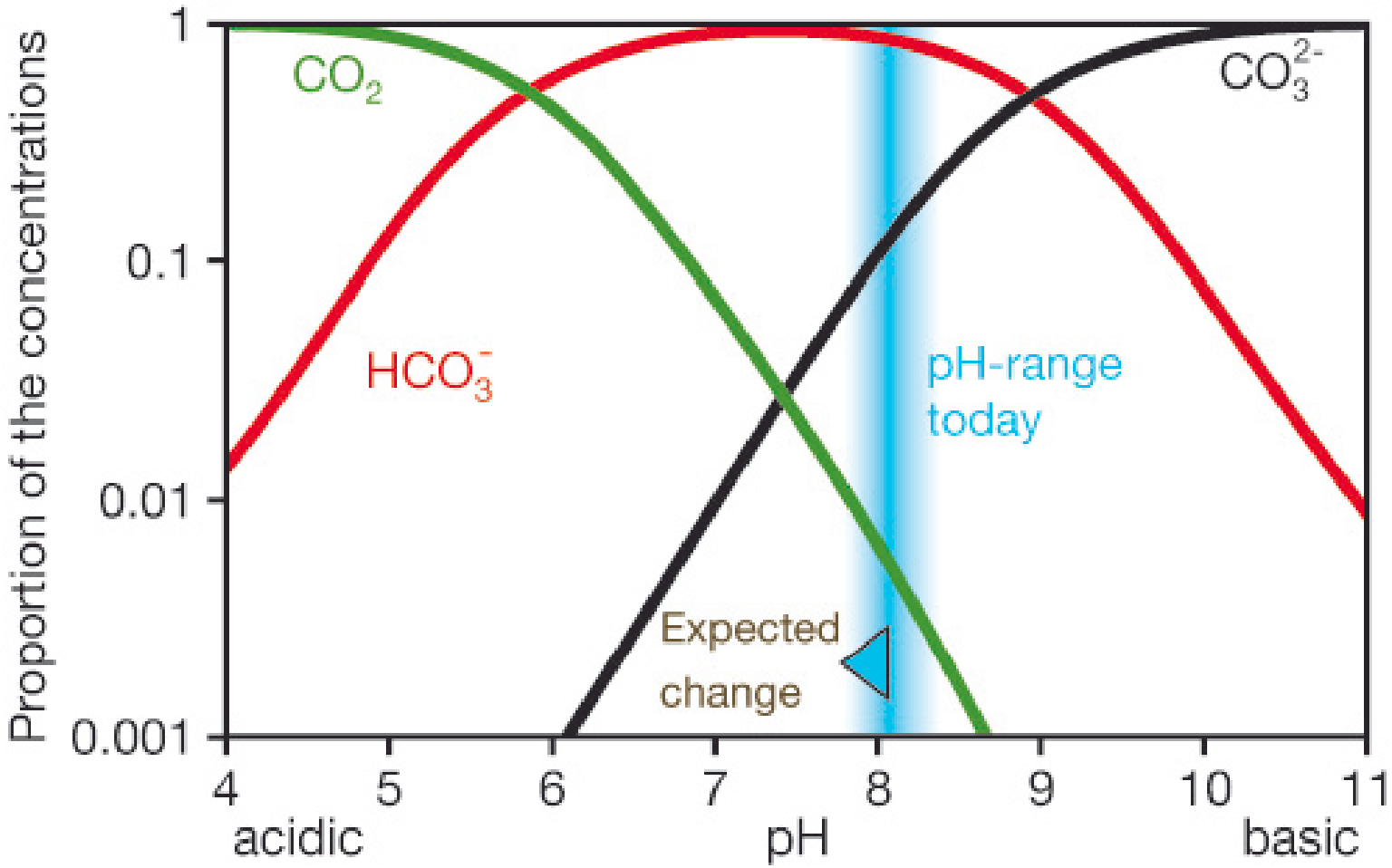


Buddemeier et al, 2004

Ocean acidification



Buddemeier et al, 2004

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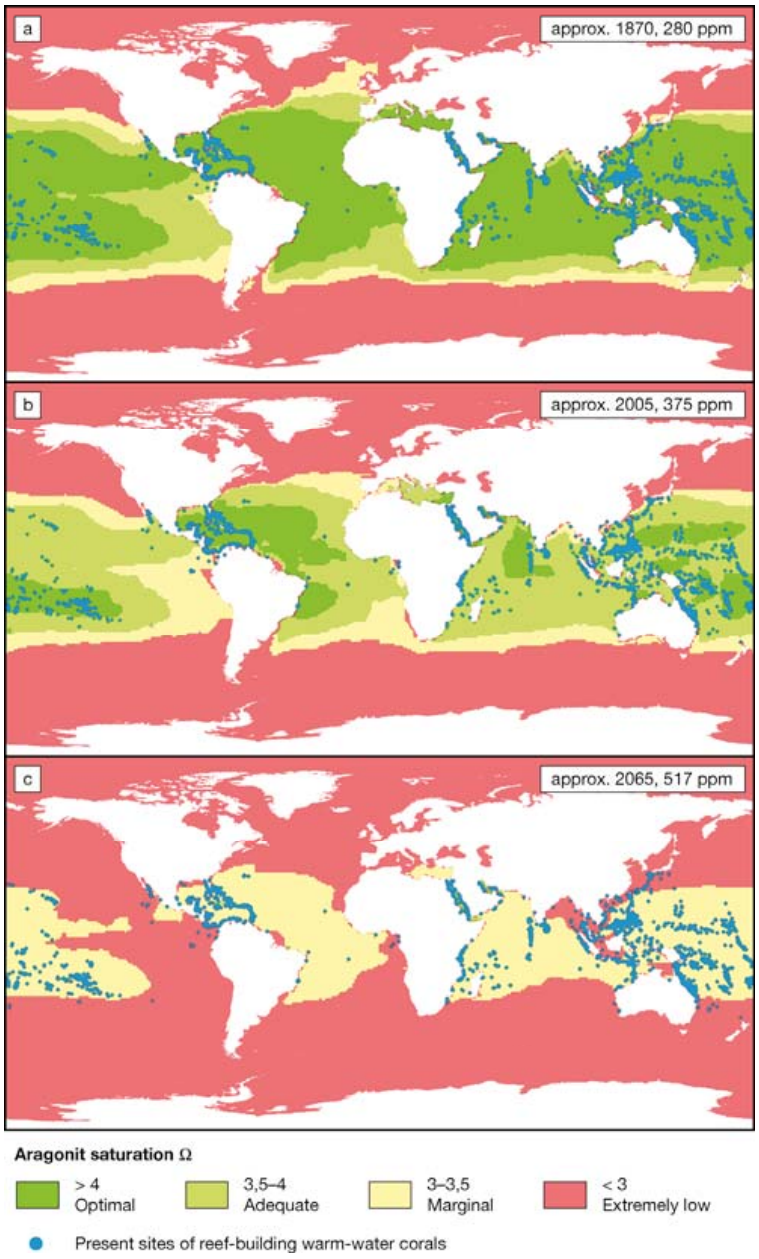
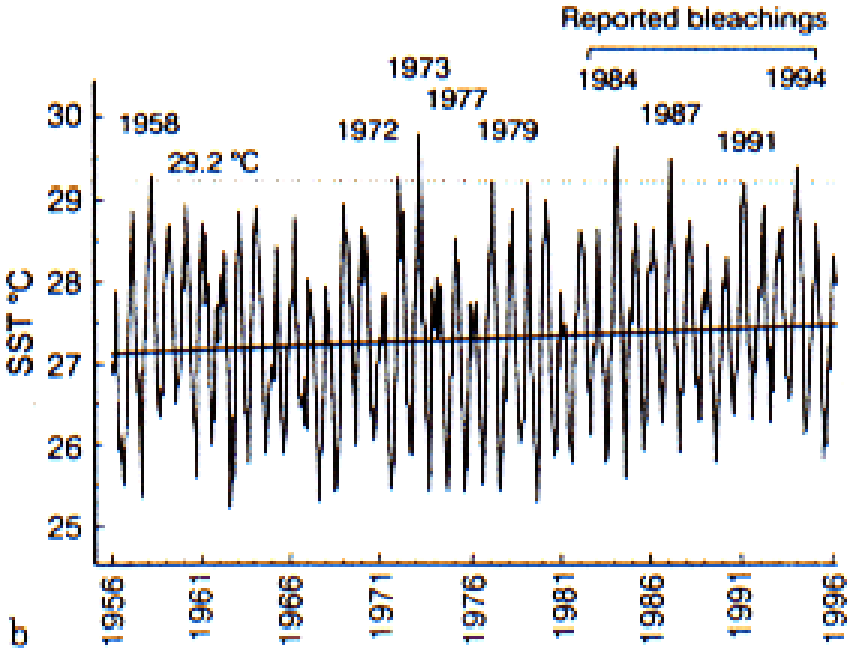


Guinotte et al, 2003

Ocean temperature increases

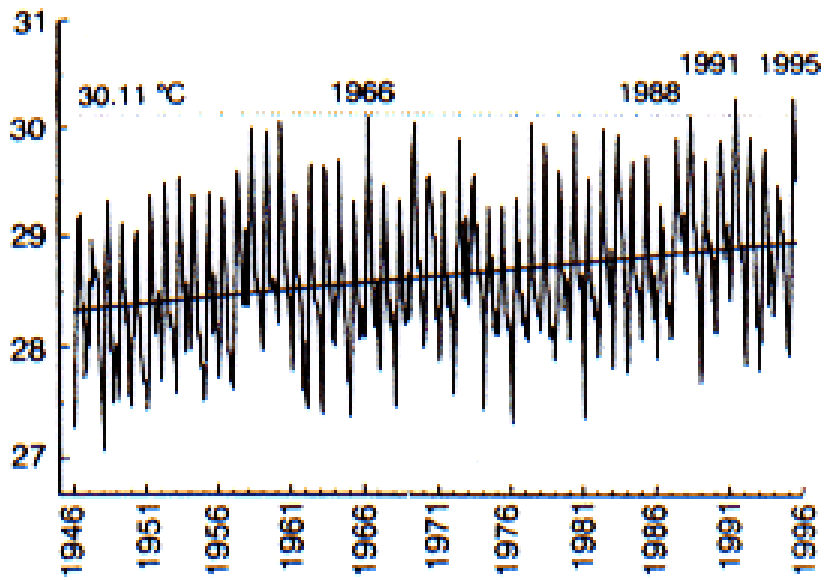
Tahiti

0.08 ° C increase/decade (P < 0.02)



Thailand

0.126 ° C increase/decade (P < 0.001)



Projected 1-2 ° C increase by 2030-2050

from Brown 1997

Ocean temperature increases

Increases in Caribbean Sea Surface Temperature (Puerto Rico 1966-1995)

Severe bleaching events

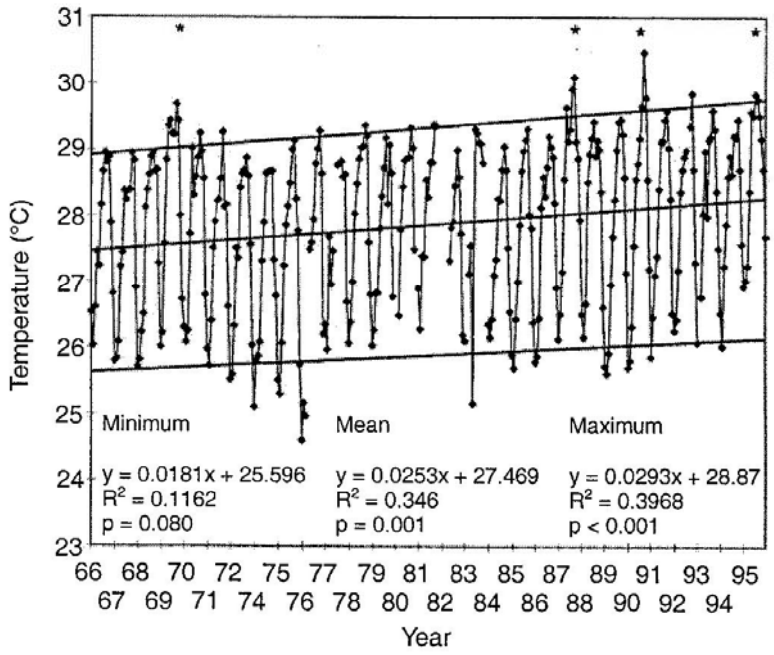
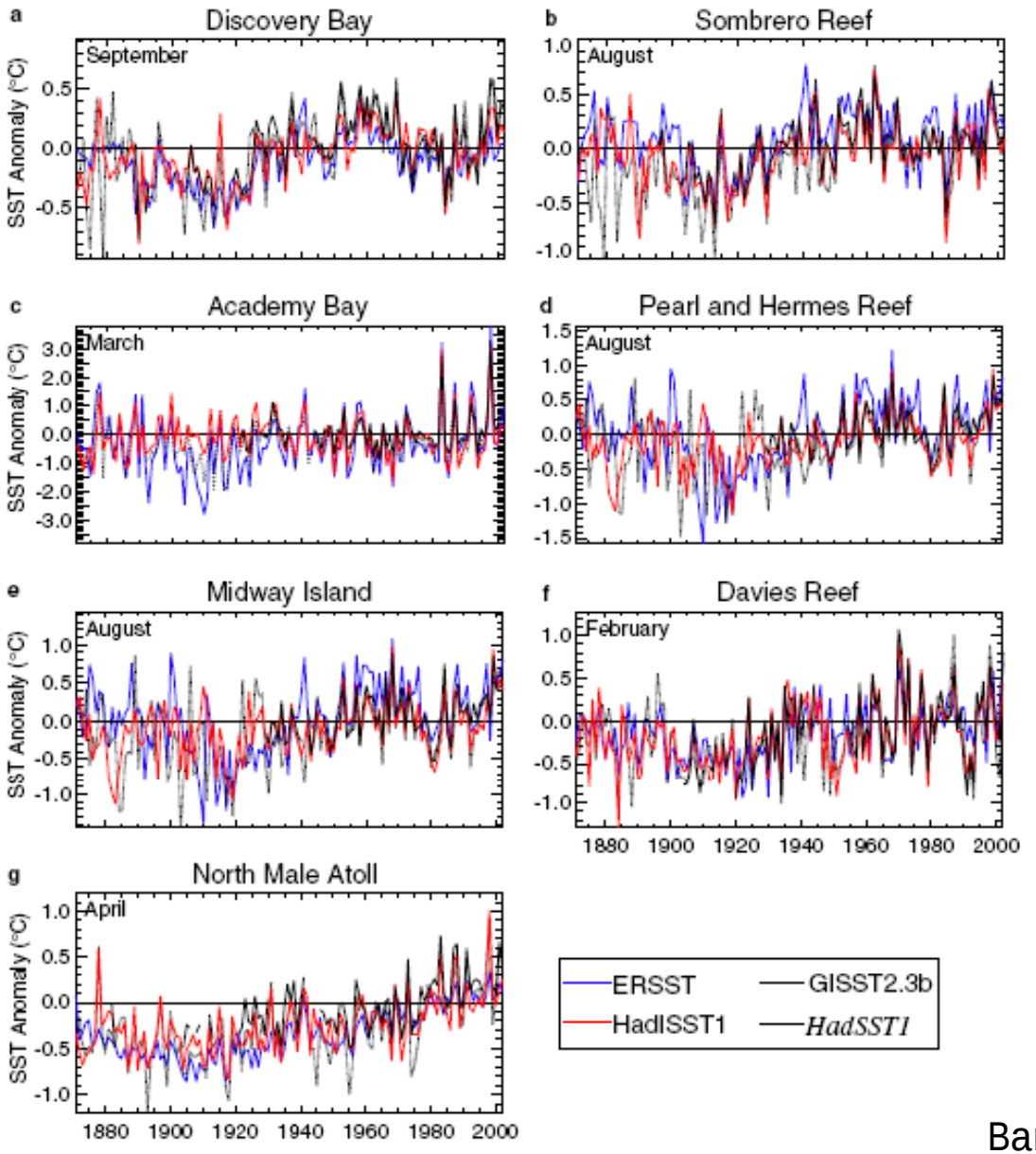


Fig. 1 Thirty-year (1966–1995) time series of monthly means of sea surface temperatures taken from La Parguera, southwestern Puerto Rico. Regression lines are (top to bottom) for maximum annual monthly temperature, mean annual monthly temperature, and minimum annual monthly temperature. Regression equations are given at the bottom. Asterisks indicate years of severe coral bleaching

0.7°C increase in 30 years

Winter et al. 1998

Ocean temperature increases



Barton and Casey 2005

Ocean temperature increases: metrics for disease and bleaching

Metric	Question	Potential application
TSA	Is the temperature warmer (> 1°C) than typical summertime highs?	Bleaching
WSSTA	Is the temperature warmer (> 1°C) than usual for that week of the year?	Disease

Other metrics: magnitude/intensity, regional metrics, different threshold values

Ocean temperature increases: bleaching

El Niño events

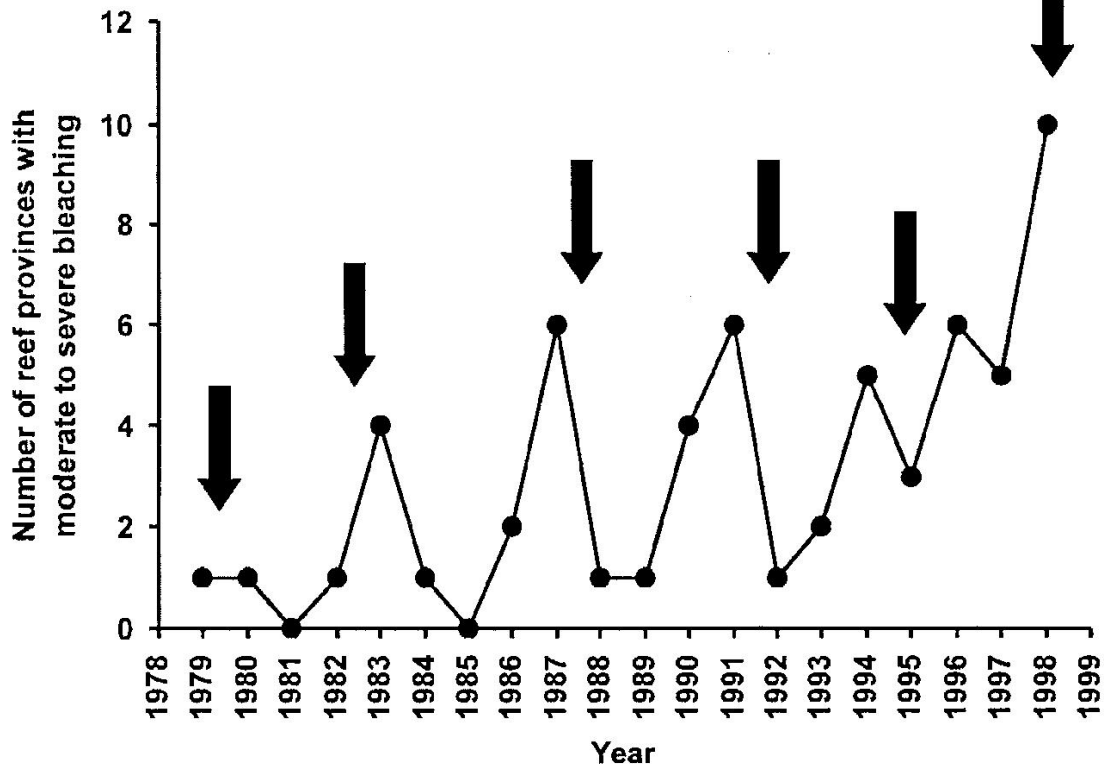
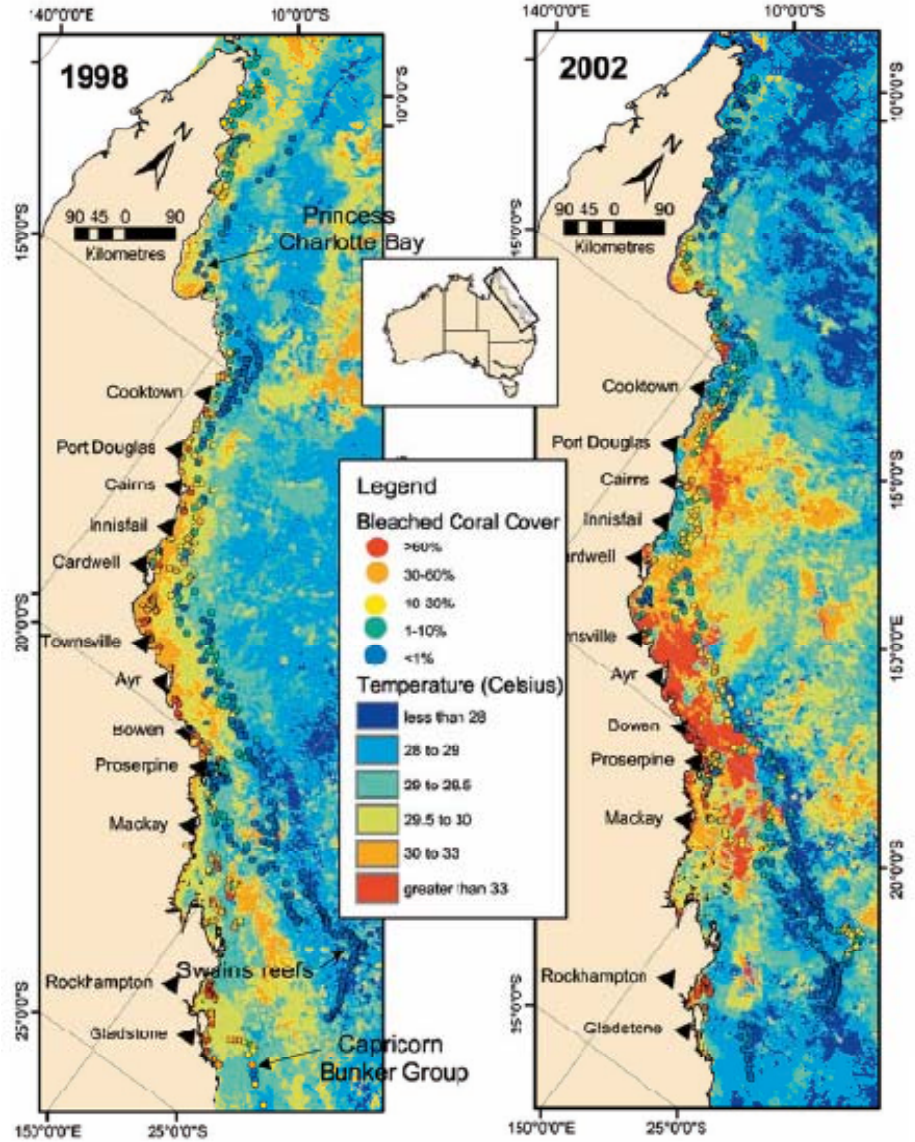


Fig. 3. Number of reef provinces bleaching since 1979. (Graph modified from Goreau and Hayes (1994) with data added for 1992 onwards.) Arrows indicate strong El Niño years.

Hoegh-Guldberg 1999

Ocean temperature increases: bleaching



Berkelmans et al 2004

Ocean temperature increases: bleaching

1998 global bleaching reports:

compiled by C. Wilkinson

Regions of the World	% reef destroyed pre 1998	% reef destroyed in 1998
Arabian Region	2	33
Wider Indian Ocean	13	46
Australia, Papua New Guinea	1	3
Southeast & East Asia	16	18
Wider Pacific Ocean	4	5
Caribbean Atlantic	21	1
Status 2000 Global *	**11**	**16**

Ocean temperature increases: Adaptive bleaching hypothesis

- Physiological response is related to host and symbiotic algae
- Symbionts have differential responses to stress
- Multiple types of symbionts and shosts are on reefs
- Frequent bleaching favors stress-resistant symbionts (which may be less competitive in a lower stress environment)

Buddemeier and Fautin, 1993

Ocean temperature increases: bleaching

Possible adaptive responses to increased ocean temperatures

- 0.2-1.0 °C per decade increased thermal tolerance?
- Shift to more tolerant species?
- Role of climate variability?

Coral bleaching, Guam, Mariana Islands (David Burdick)

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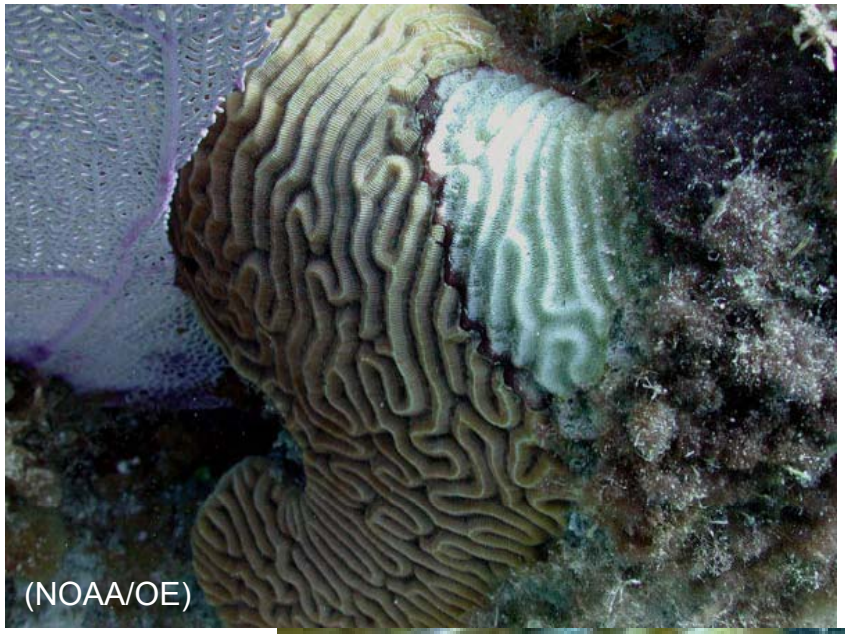
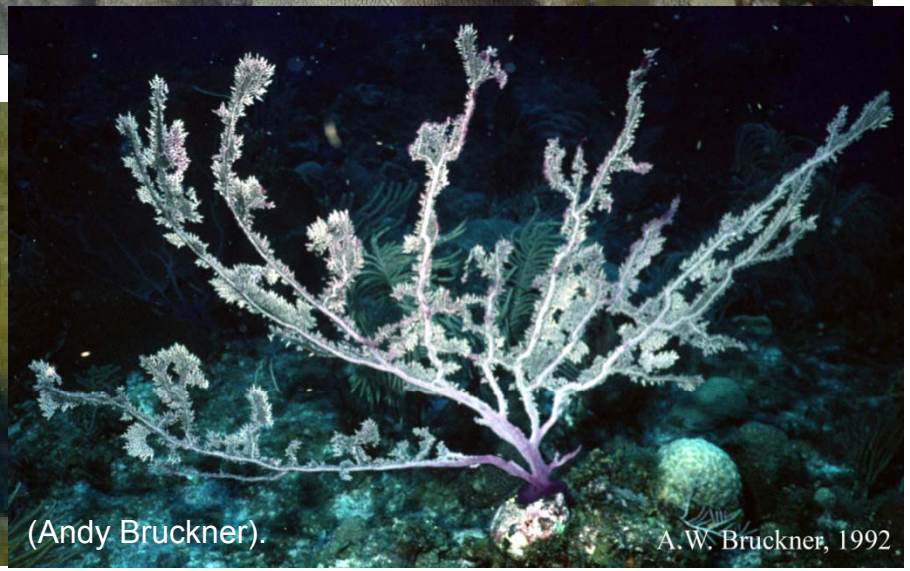
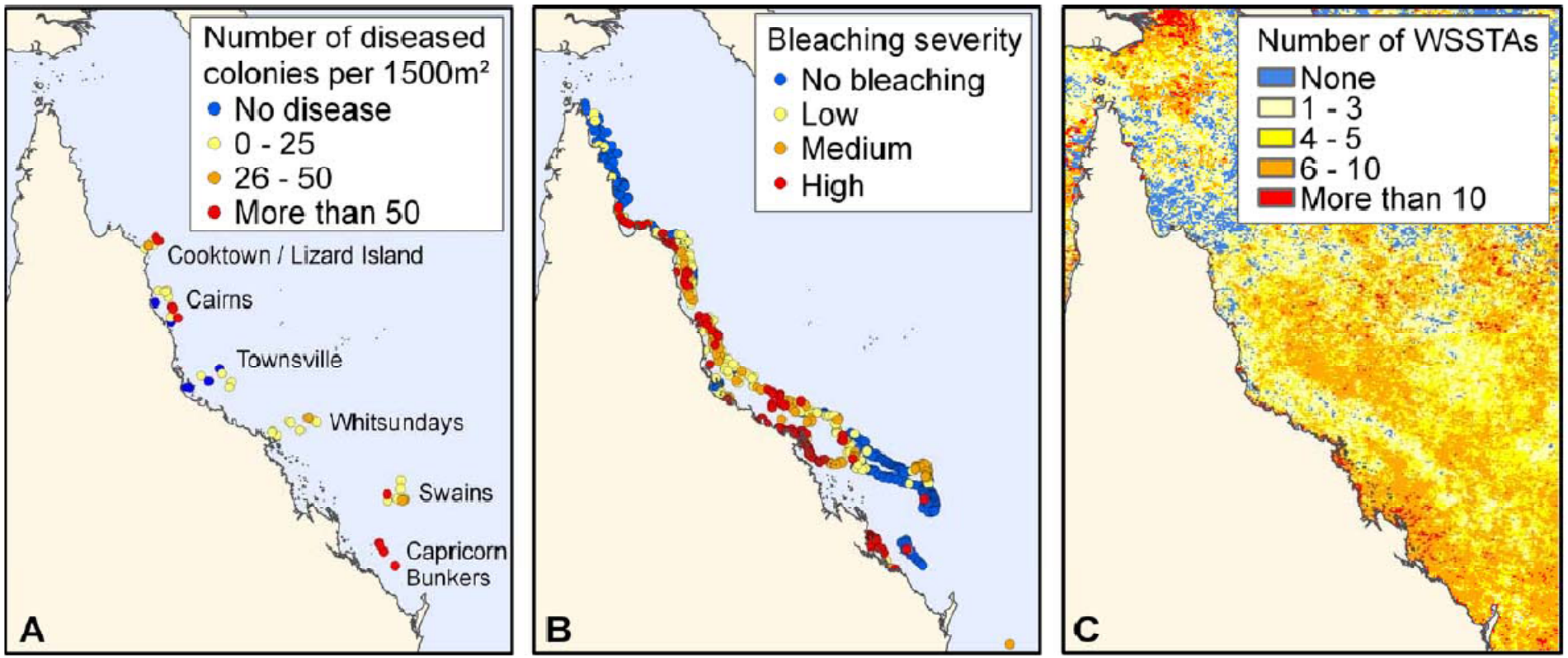
Ocean temperature increases: disease





Clockwise: Black band, yellow band, aspergillosis, and white pox

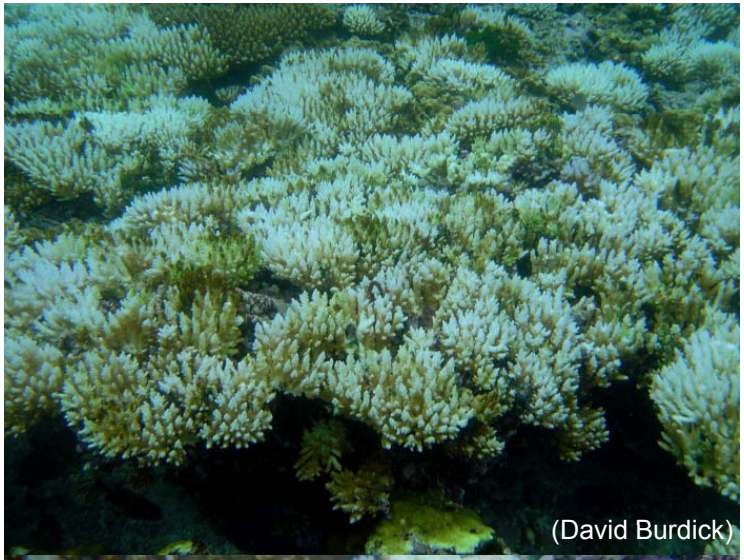
White syndrome and increases in ocean temperature



Bruno et al 2007

Ocean temperature increases: bleaching and disease

- More frequent and severe bleaching
- More mass bleaching events
- More severe El Niño cycles
- Increased disease prevalence and severity



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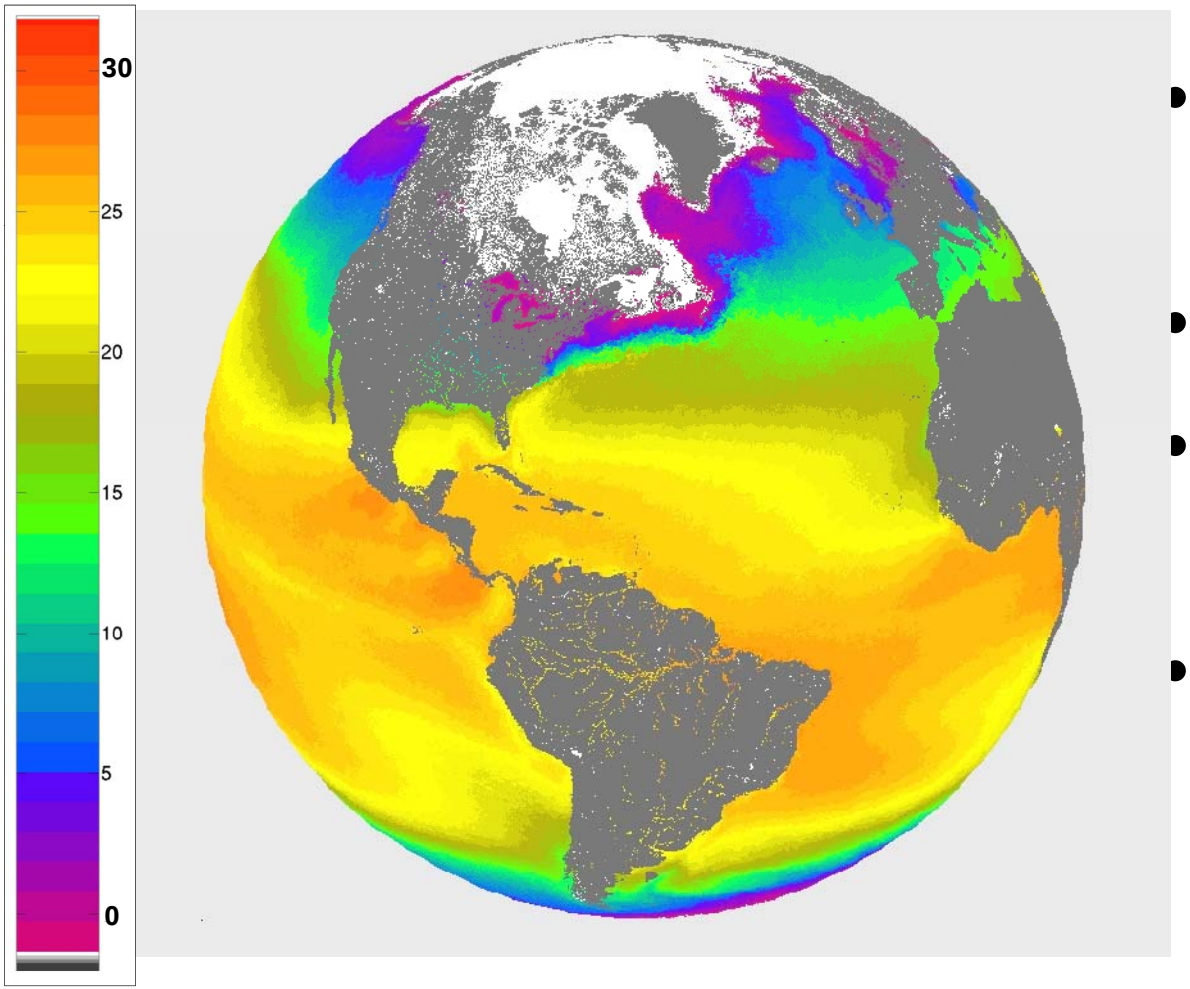
Great Barrier Reef (Robert Ricker)

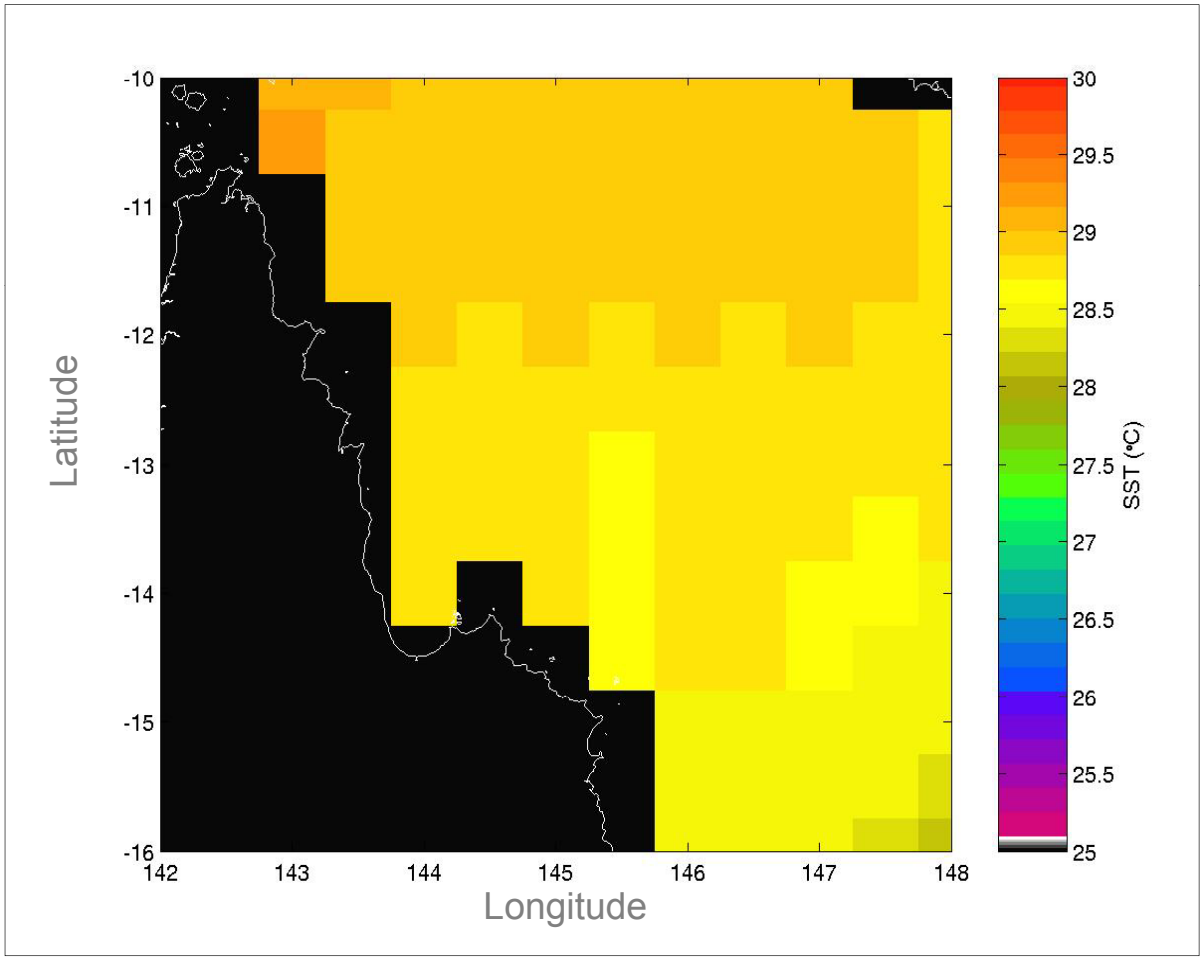
Studying temperature patterns: Coral Reef Temperature Anomaly Database (CoRTAD)



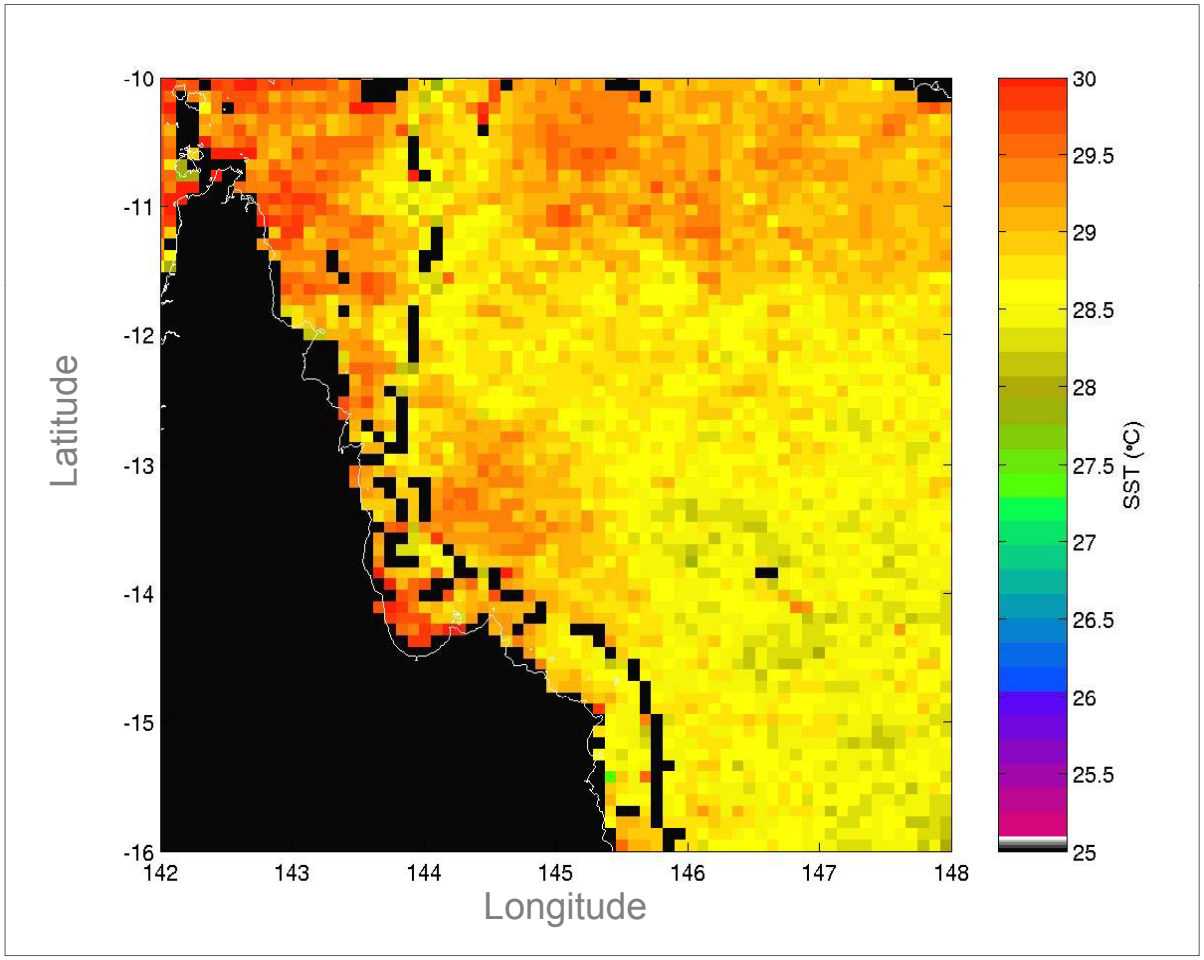
- 1985-near present
- 4km resolution
- AVHRR sensor (Pathfinder)
- global

http://pathfinder.nodc.noaa.gov

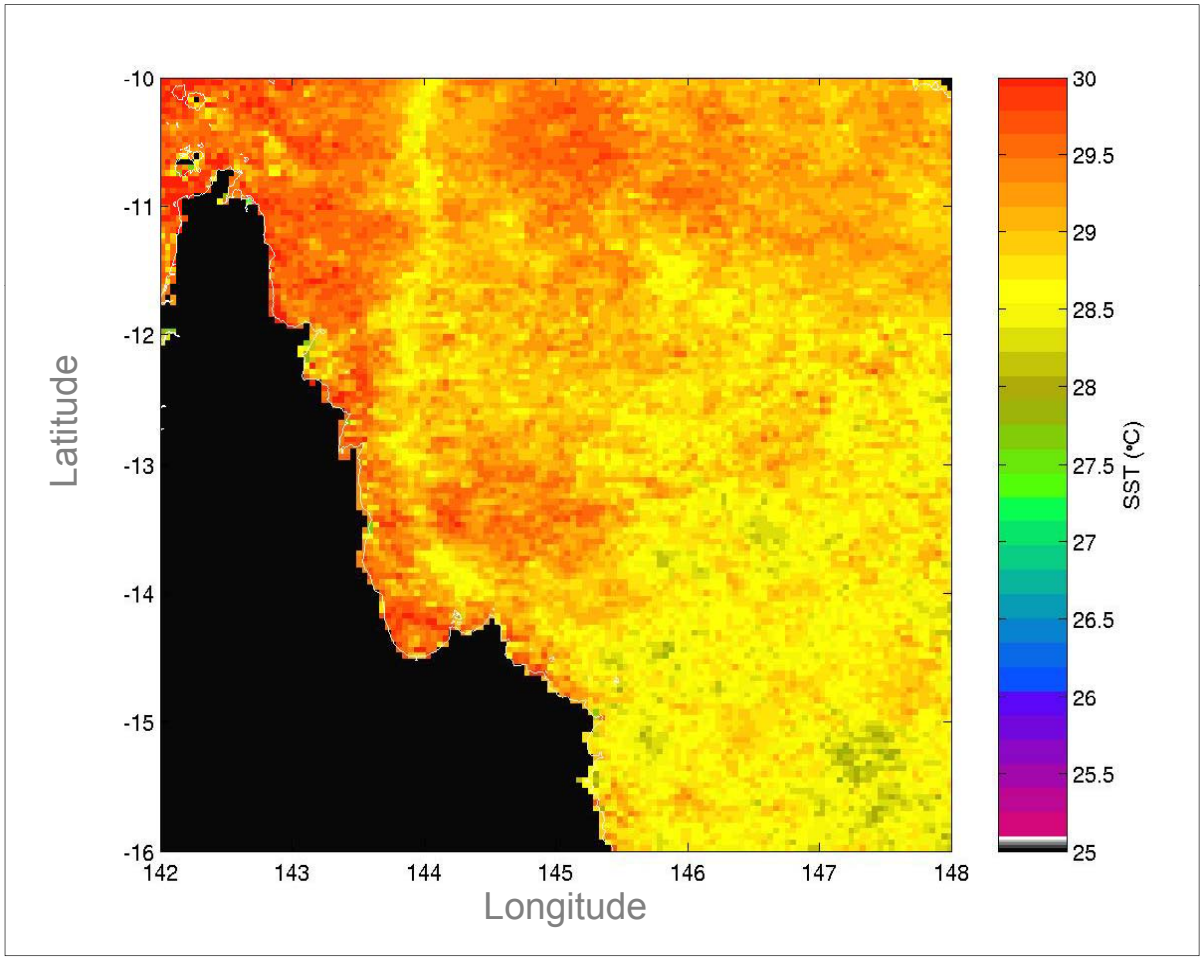
Operational NESDIS 50 km Hotspot Mapping



NOAA/NASA
AVHRR Pathfinder 9 km

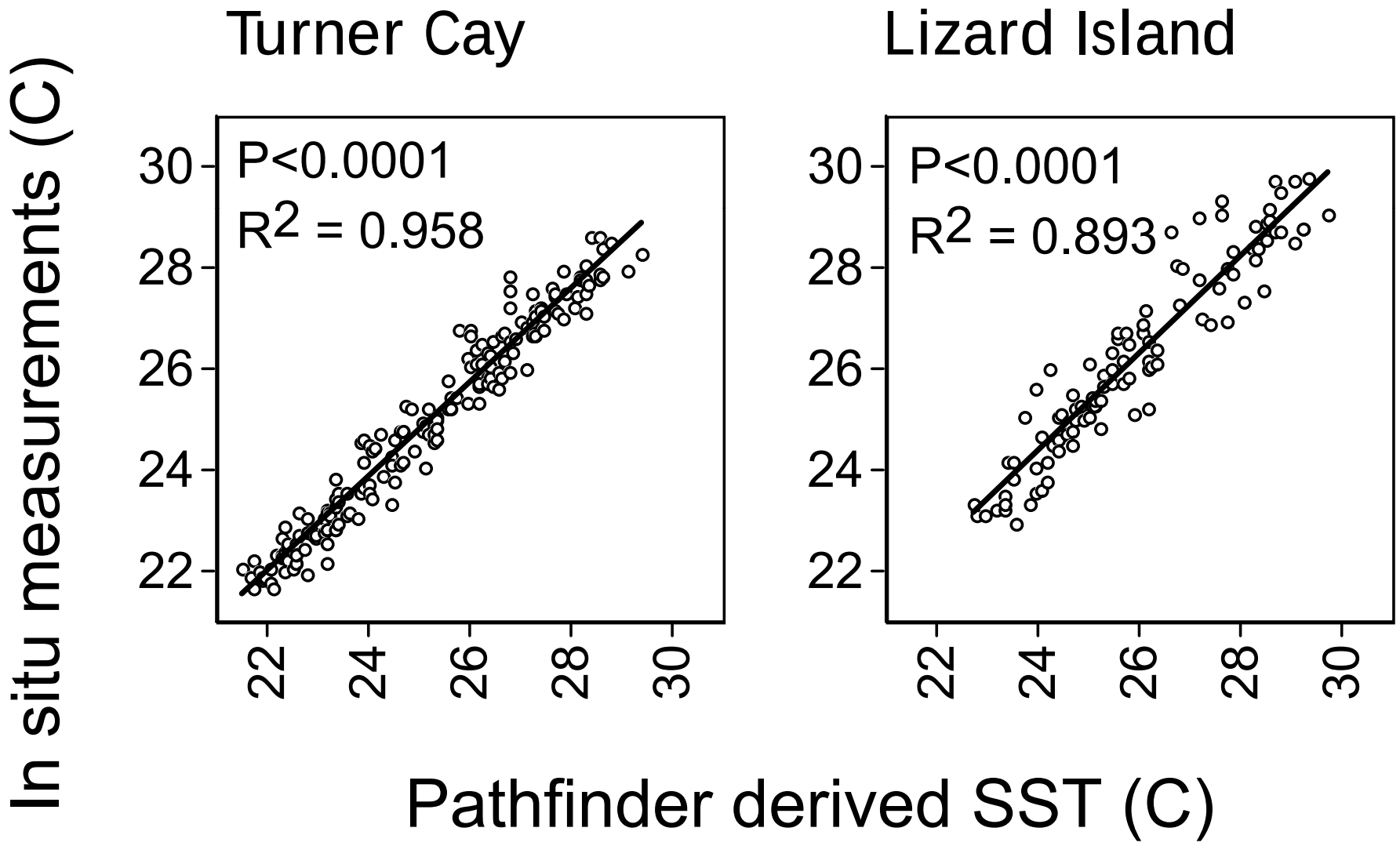


RSMAS/NODC
AVHRR Pathfinder 4 km



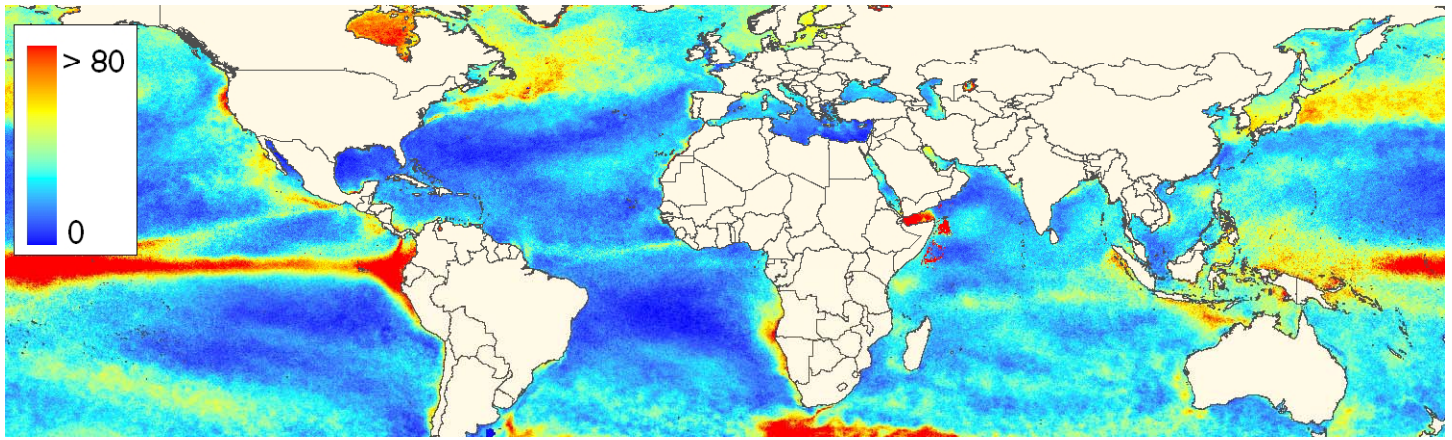
Satellite versus *In situ* measurements

(Data from GBRMPA; *In situ* loggers at 5-10m depth)

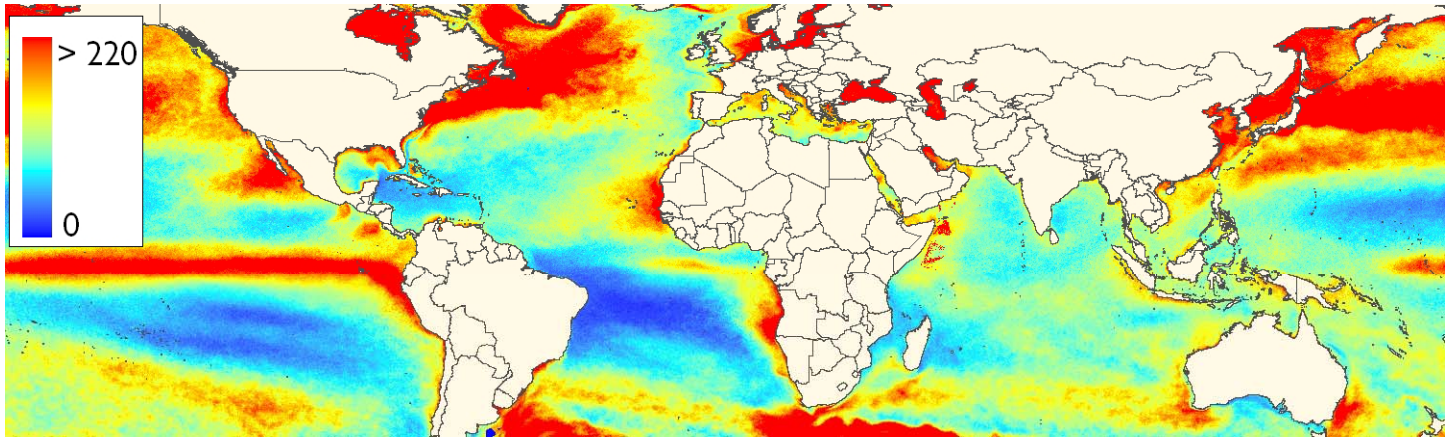


Spatial analyses of anomaly frequencies

TSA frequency 1985-2005

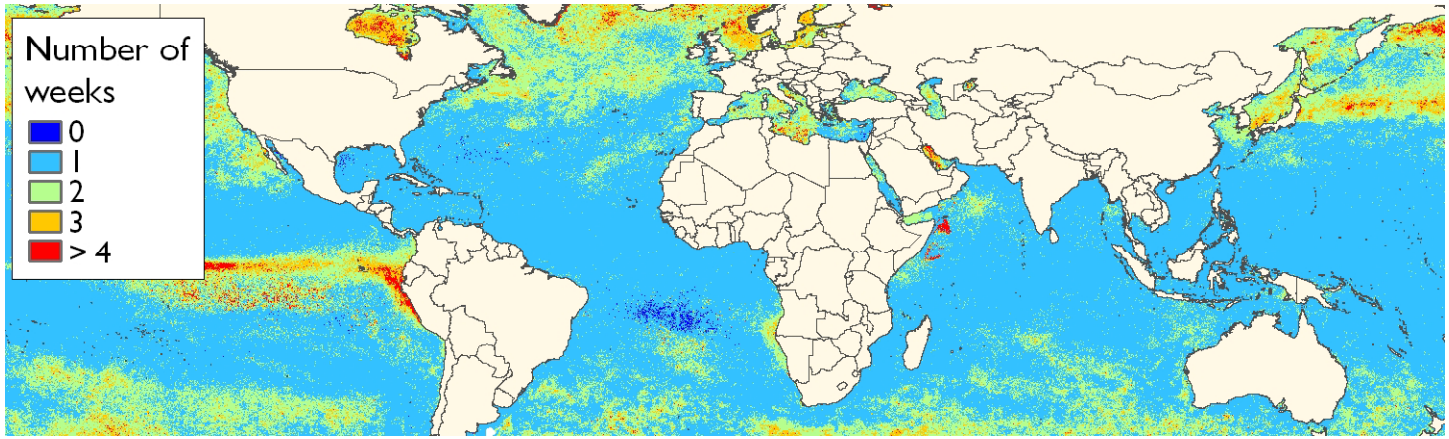


WSSTA frequency 1985-2005

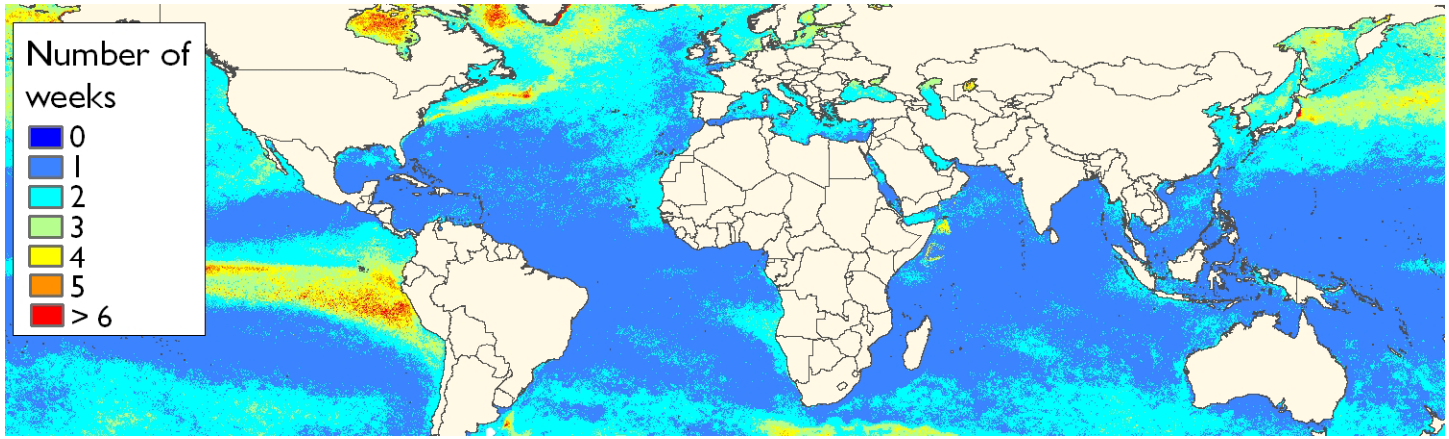


Spatial analyses of anomaly lengths

Average TSA length



Average WSSTA length



Climate change effects on coral reefs

- Habitat loss due to reef drowning, reduced reef building and erosion due to acidification and loss of marginal habitats
- Species loss due to the loss of less acclimated coral species or those susceptible to thermally driven disease outbreaks