

A large, mushroom-shaped coral reef structure in a clear blue ocean. The coral is dark brown and has a thick, rounded top. The water is a deep blue, and there are other smaller coral structures visible in the background.

SPACE-FOR-TIME:

Elucidating the thermal and chemical ramifications of climate change on coral reefs with real-world examples

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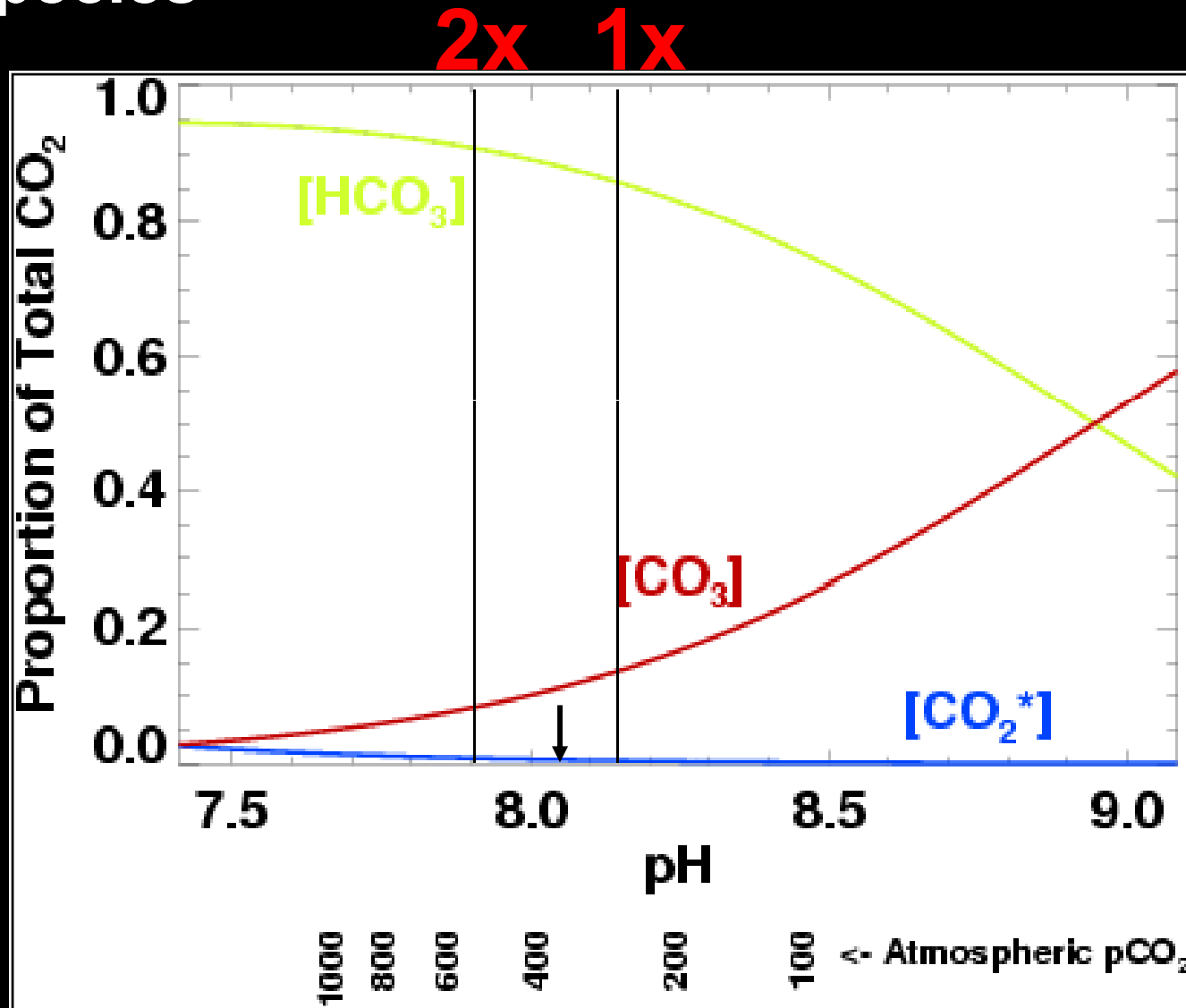
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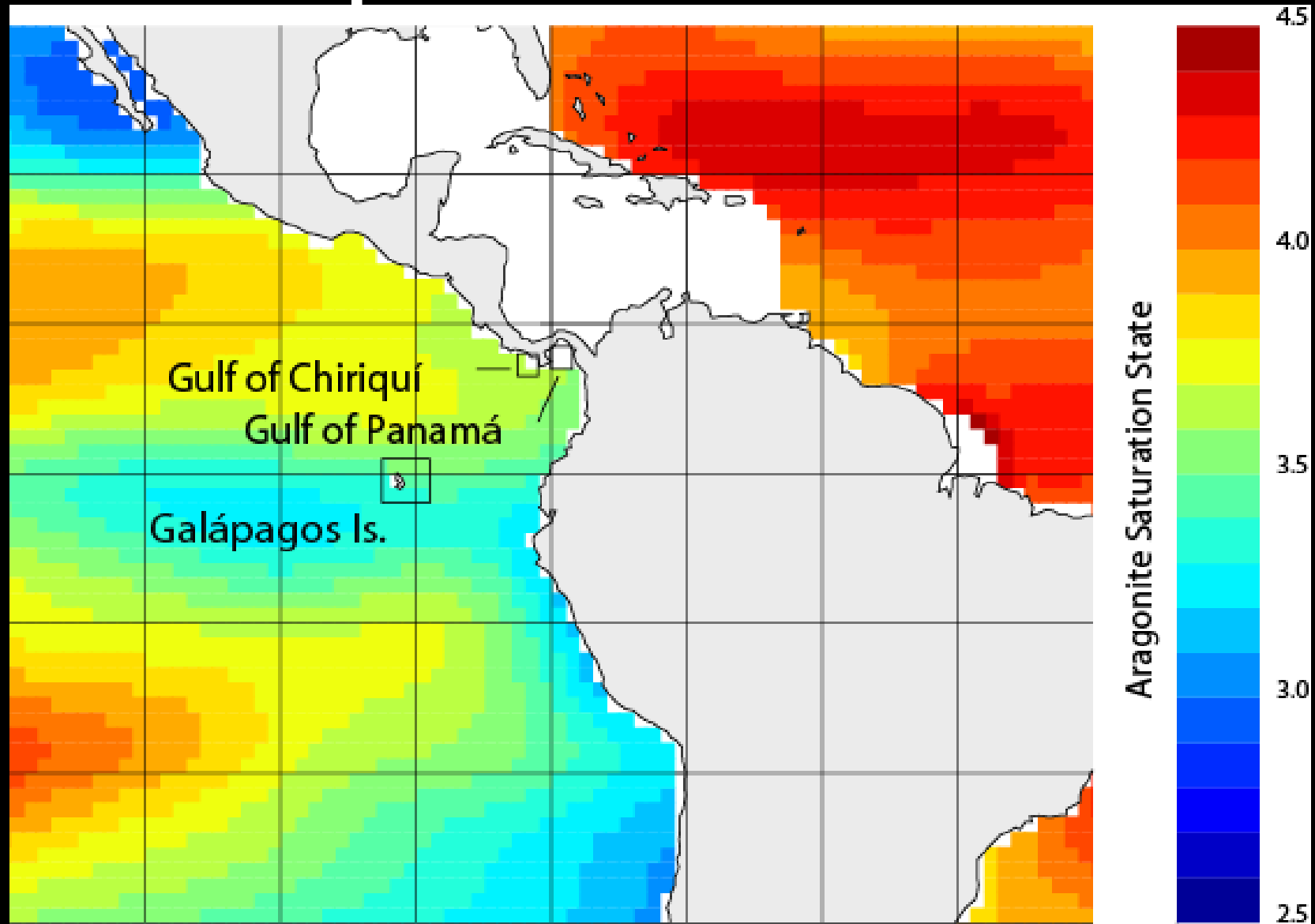
Ocean Acidification and the Proportion of Carbonate Species



$$\Omega = \frac{[\text{Ca}^{2+}][\text{CO}_3^{2-}]}{K'_{sp}}$$

Figure courtesy of J. A. Kleypas (NCAR)

Space-for-time and the eastern tropical Pacific Ocean

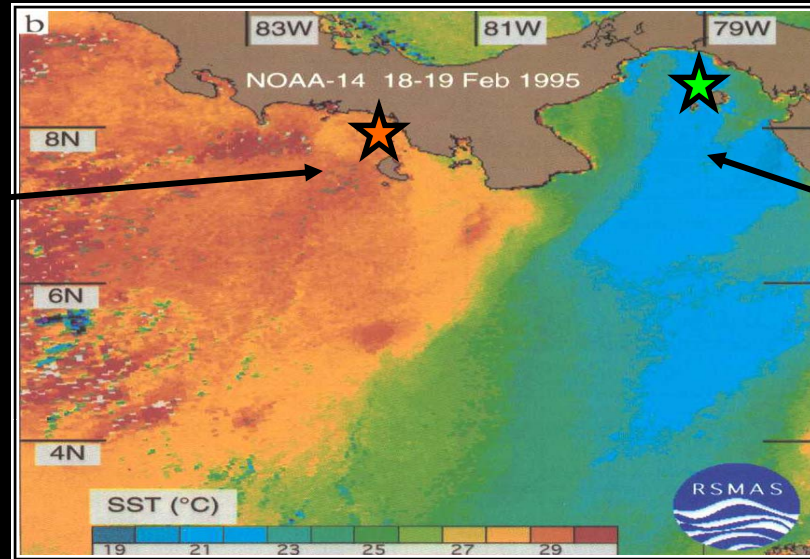
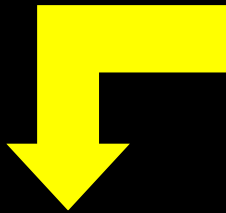


Research sites



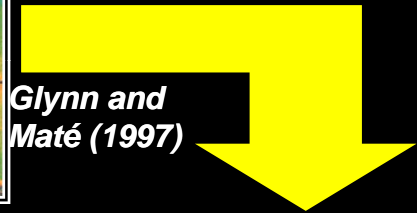
Pacific Panamá

Gulf of Chiriquí



Gulf of Panamá

Glynn and Maté (1997)

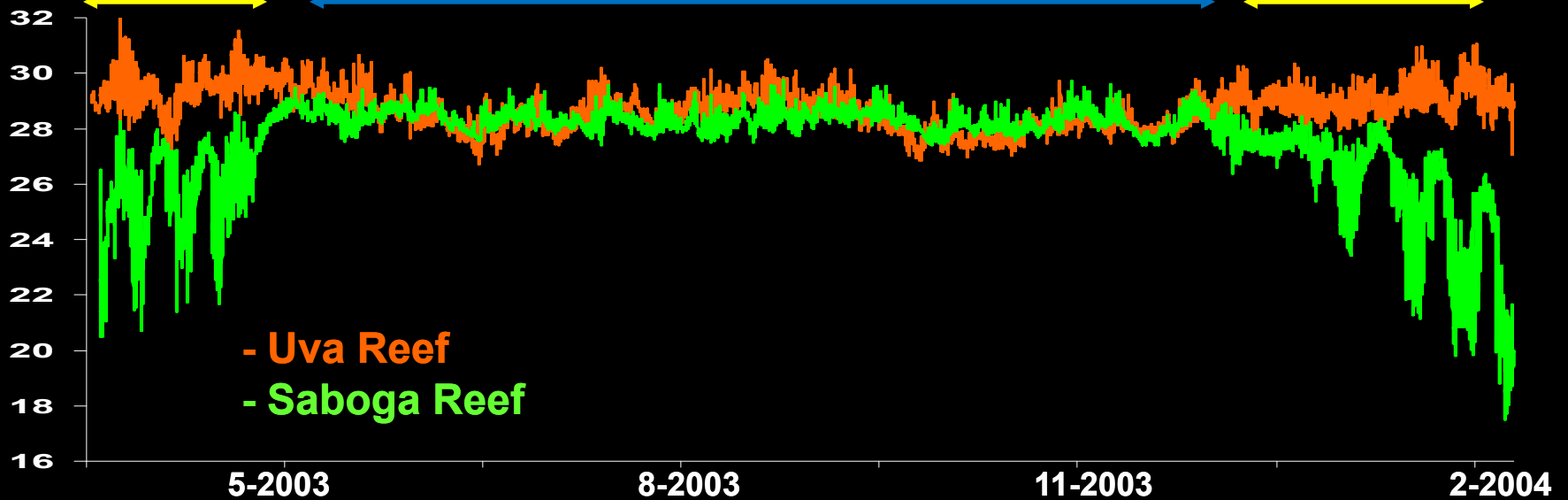


Dry Season

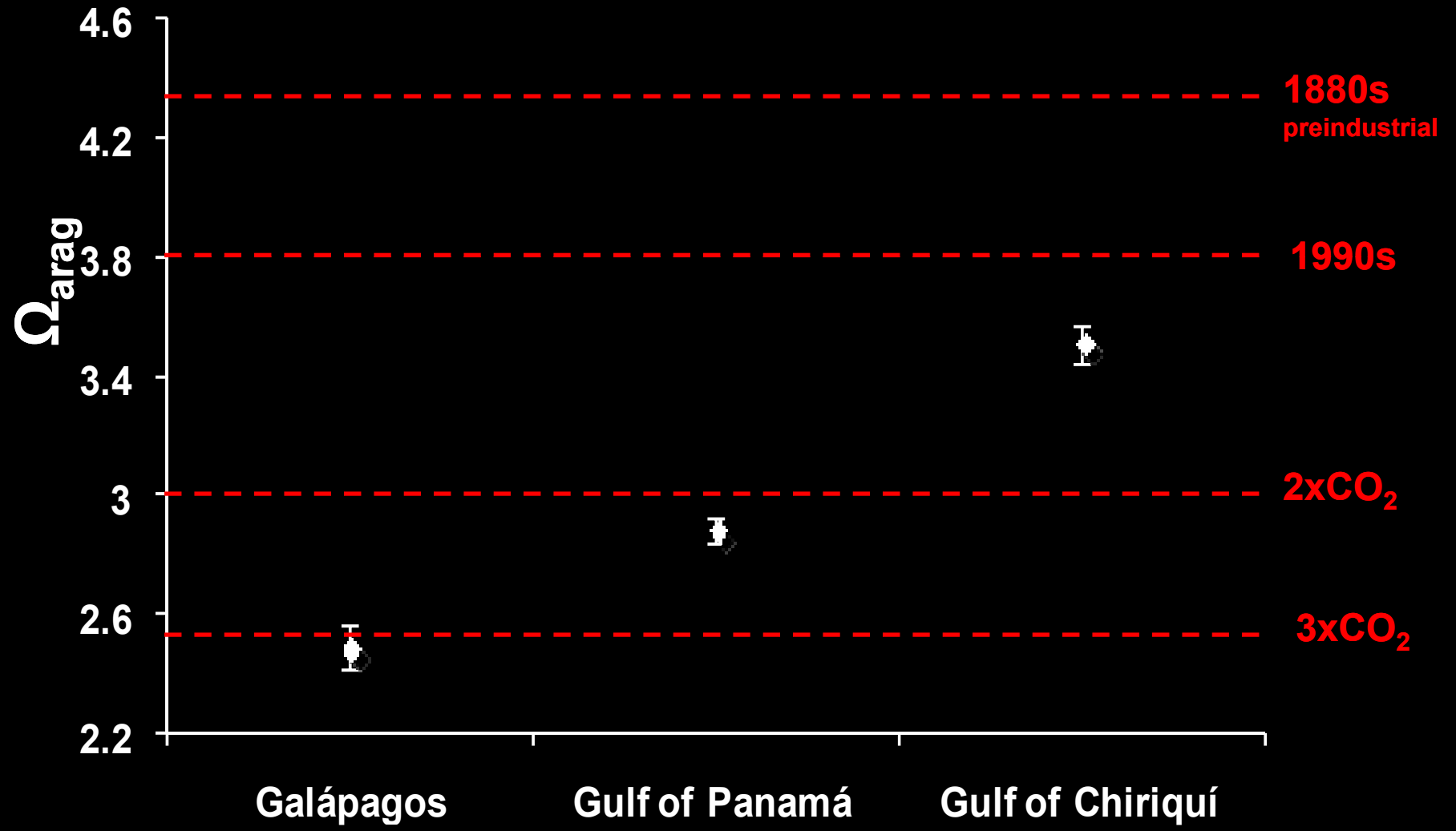
Wet Season

Dry Season

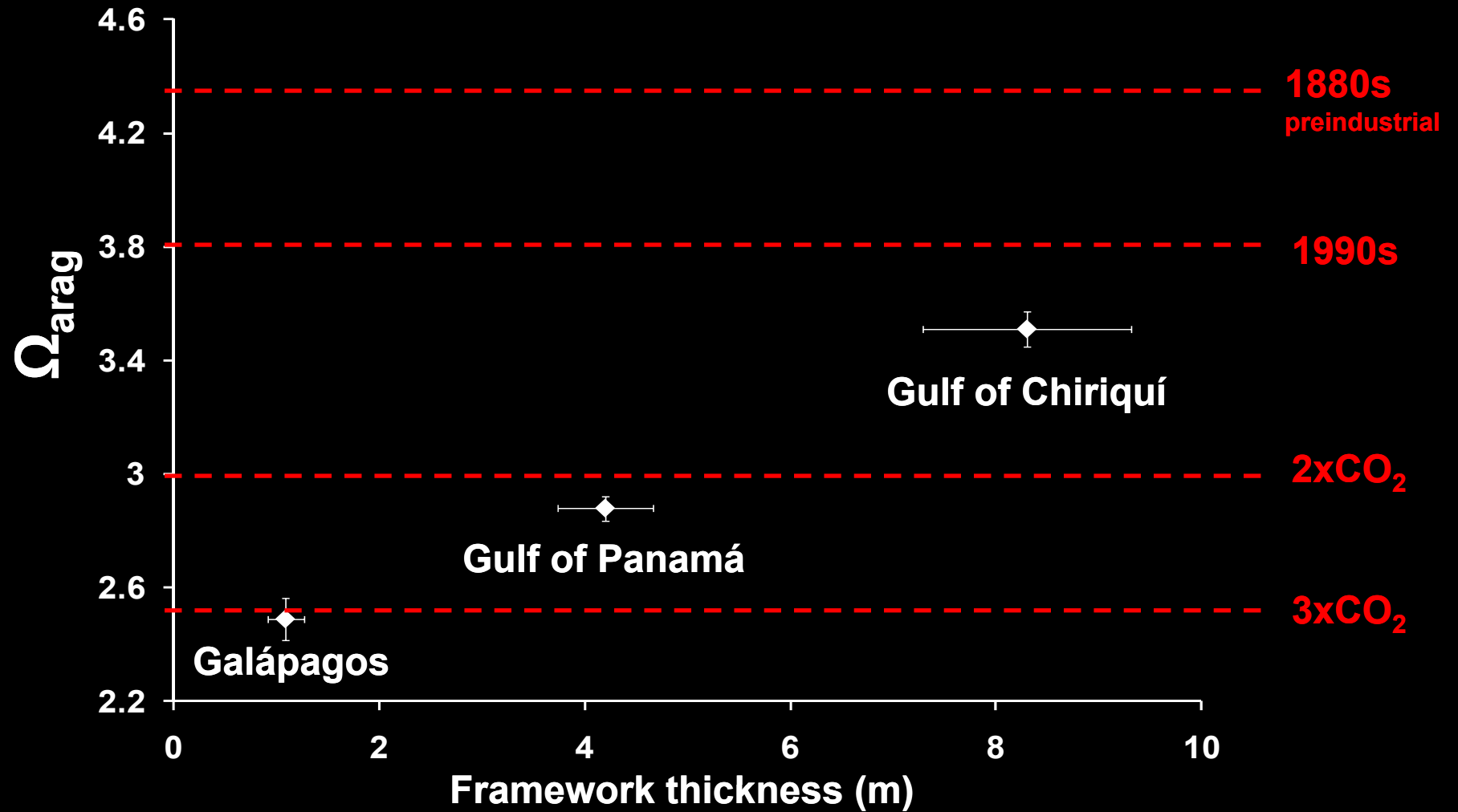
Temp (°C)



Ω_{arag}



How important is Ω_{arag} ?



Eastern Pacific Reefs: Panamá

- Key Points

- Lowest CO₂ and Highest Ω

- Greatest Reef Development of East Pacific

- High rates of bleaching mortality from 82/83 ENSO, 75-85% (Glynn 1990)

- Signs of hope?

- Very good recovery since



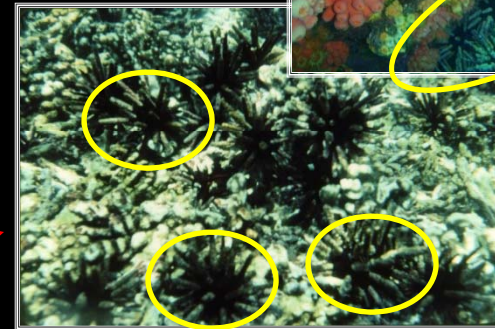
- Less bleaching during 97/98 ENSO

- Reef structures still remain

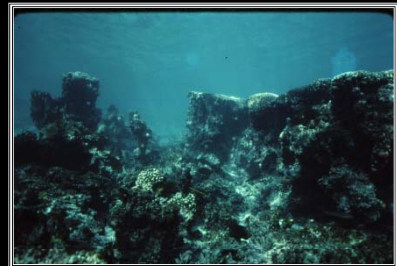


Eastern Pacific Reefs: Galápagos

ENSO thermal bleaching
= 99% Coral Mortality



Eucidaris galapagensis



1976

Pre-1982/83 ENSO



1987



1992

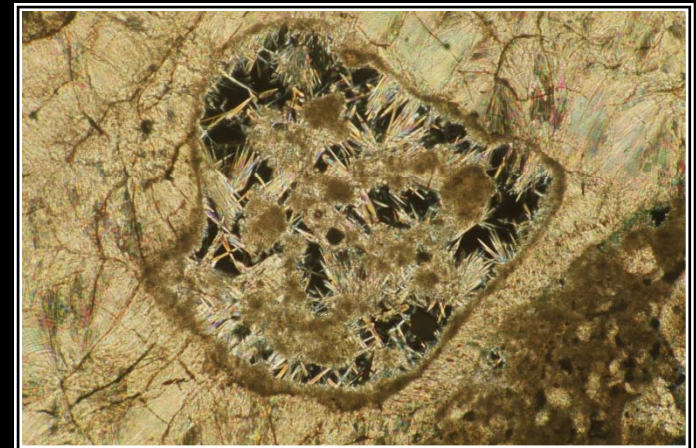


2009

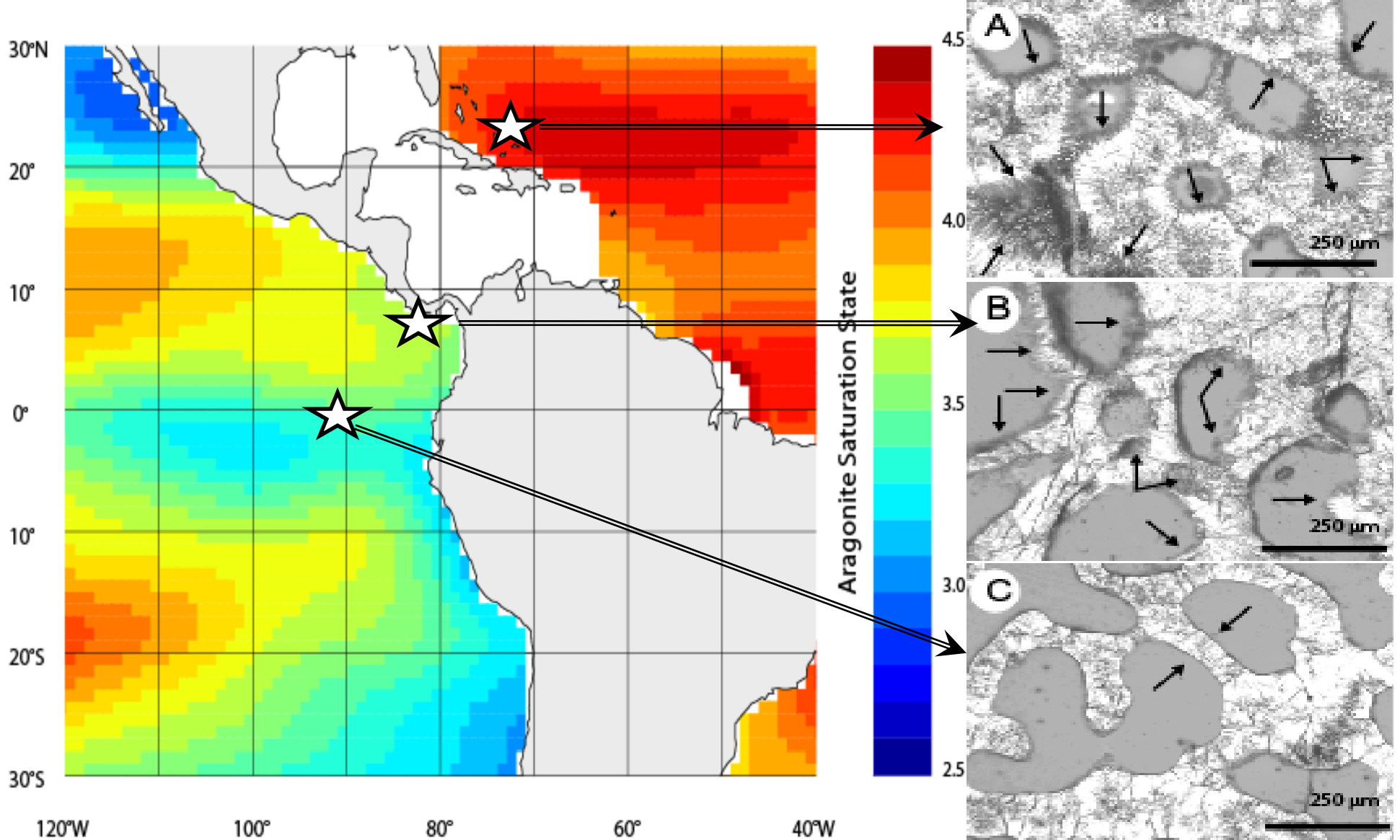
Post-1982/83 ENSO

Inorganic cementation

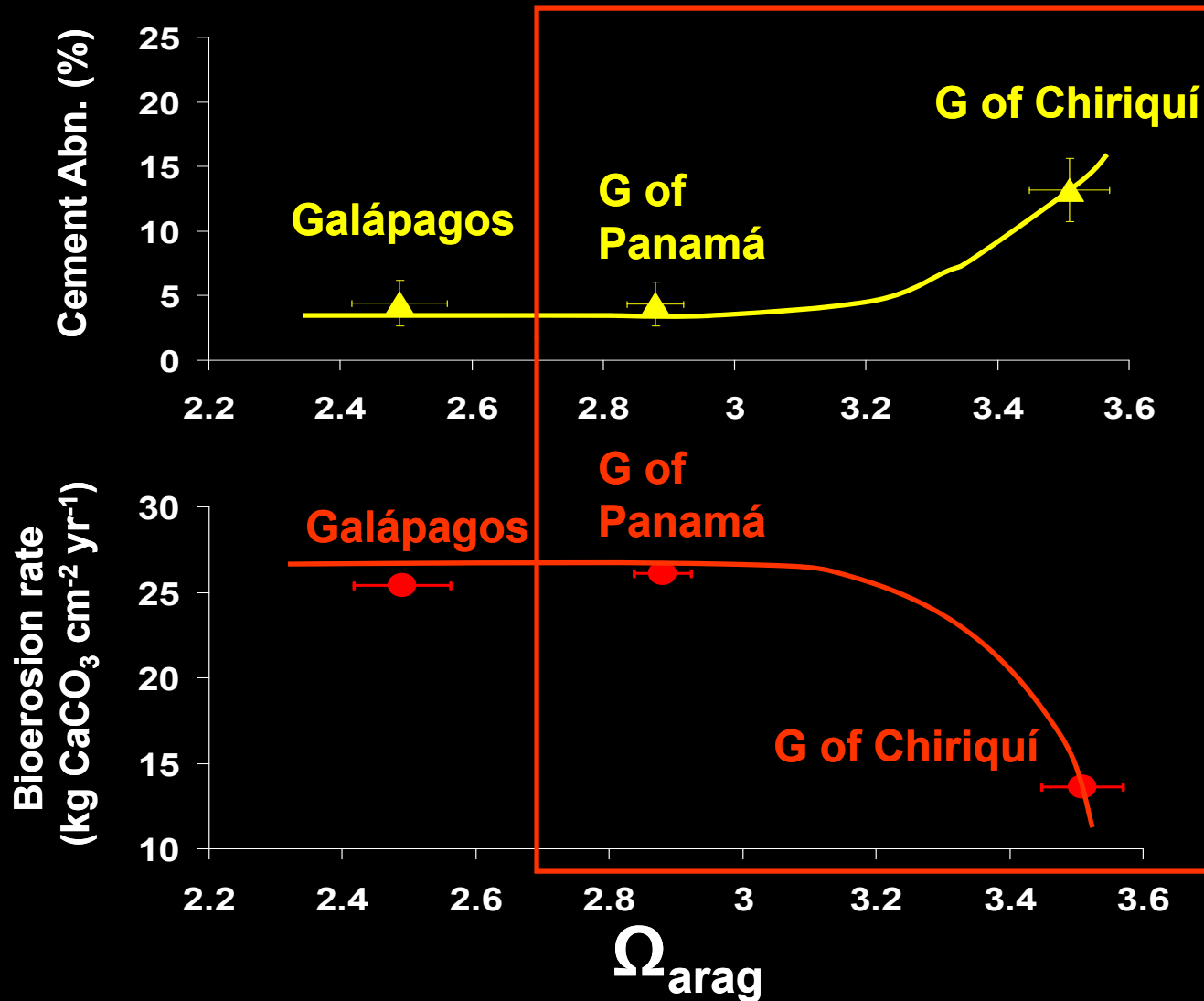
- **Secondary, CaCO_3 precipitate that “coats, infills and forms a matrix around various reef components” (Macintyre 1977, *J. Sed. Petrol.*)**
- **Usually High-Mg Calcite, aragonite**
- **“Acts to occlude and replace porosity” (Perry 1999, *J. Coastal. Res.*)**



Inorganic cementation



How important is Ω_{arag} ?

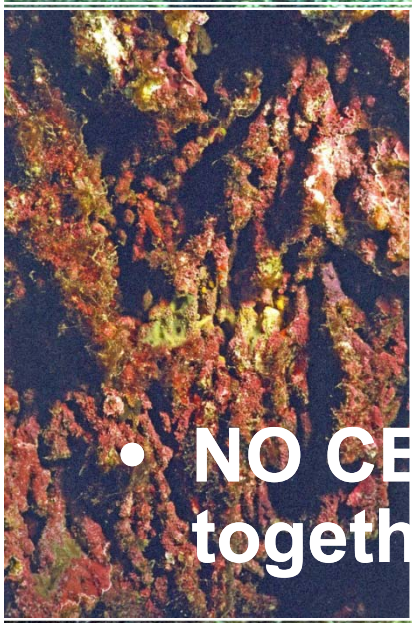


Conclusions

- **Eastern Pacific reefs are a REAL-WORLD example of coral reef growth in low Ω seawater**
- **Low Ω likely an additional factor in poor reef development**
- **First and most affected by acidification**

Secas Island Reef, Panamá
Image courtesy of T. B. Smith

Conclusions II



- **NO CEMENT** = Reef frameworks held together by CCA, sponges, and other infauna

Uva Island Reef, Panamá
Images courtesy of C. M. Eakin and T.B. Smith

Conclusions III

- **NEW reef development and accretion may be limited in a high-CO₂ world**
- **Coral reefs of the future more susceptible to erosive processes (physical, biological, AND chemical)**
- **Poorest resilience where CO₂ highest in Galápagos**



Acknowledgements

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