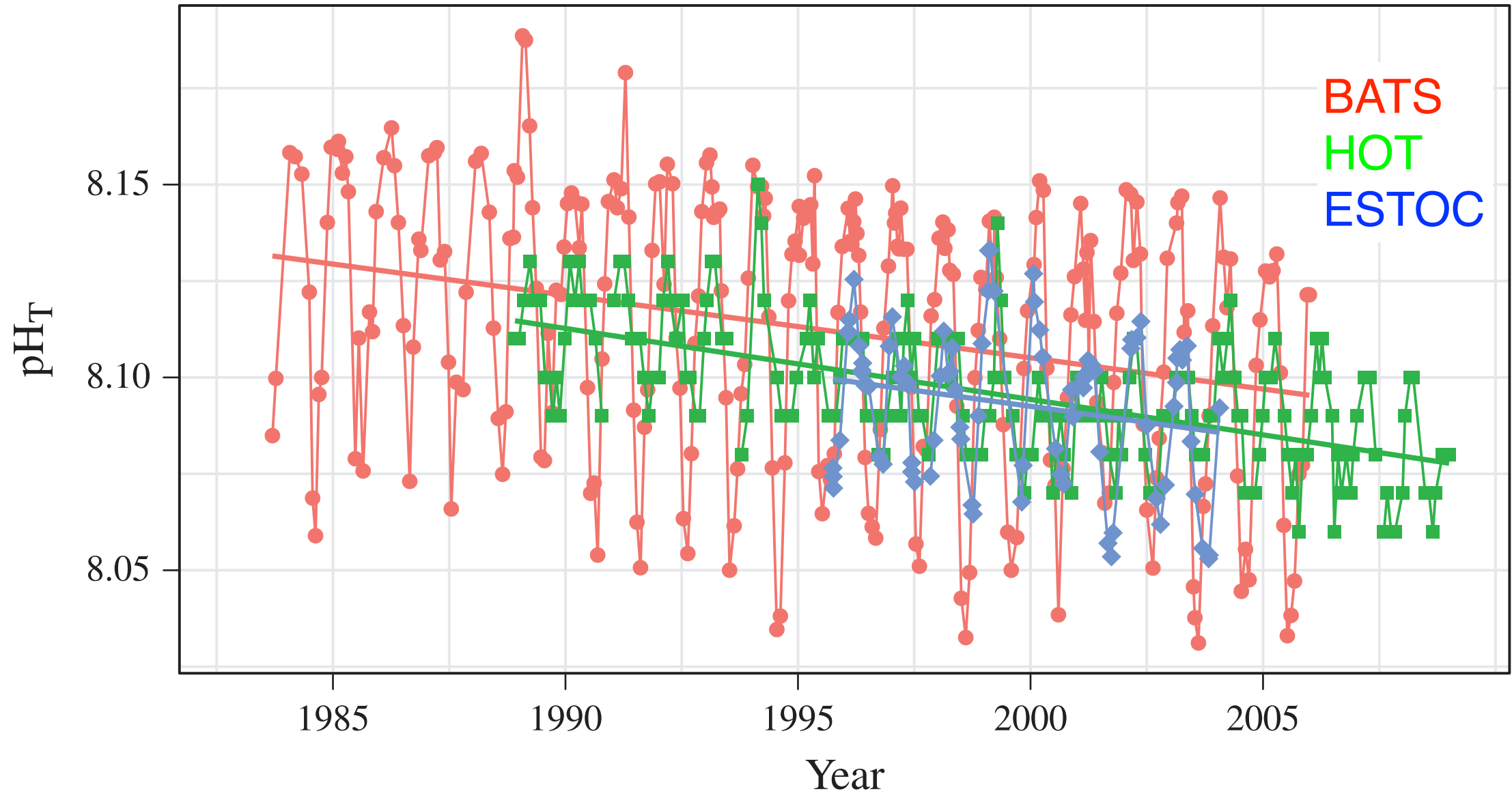


# Responses to future climate change: biogeochemistry

**Jean-Pierre Gattuso**

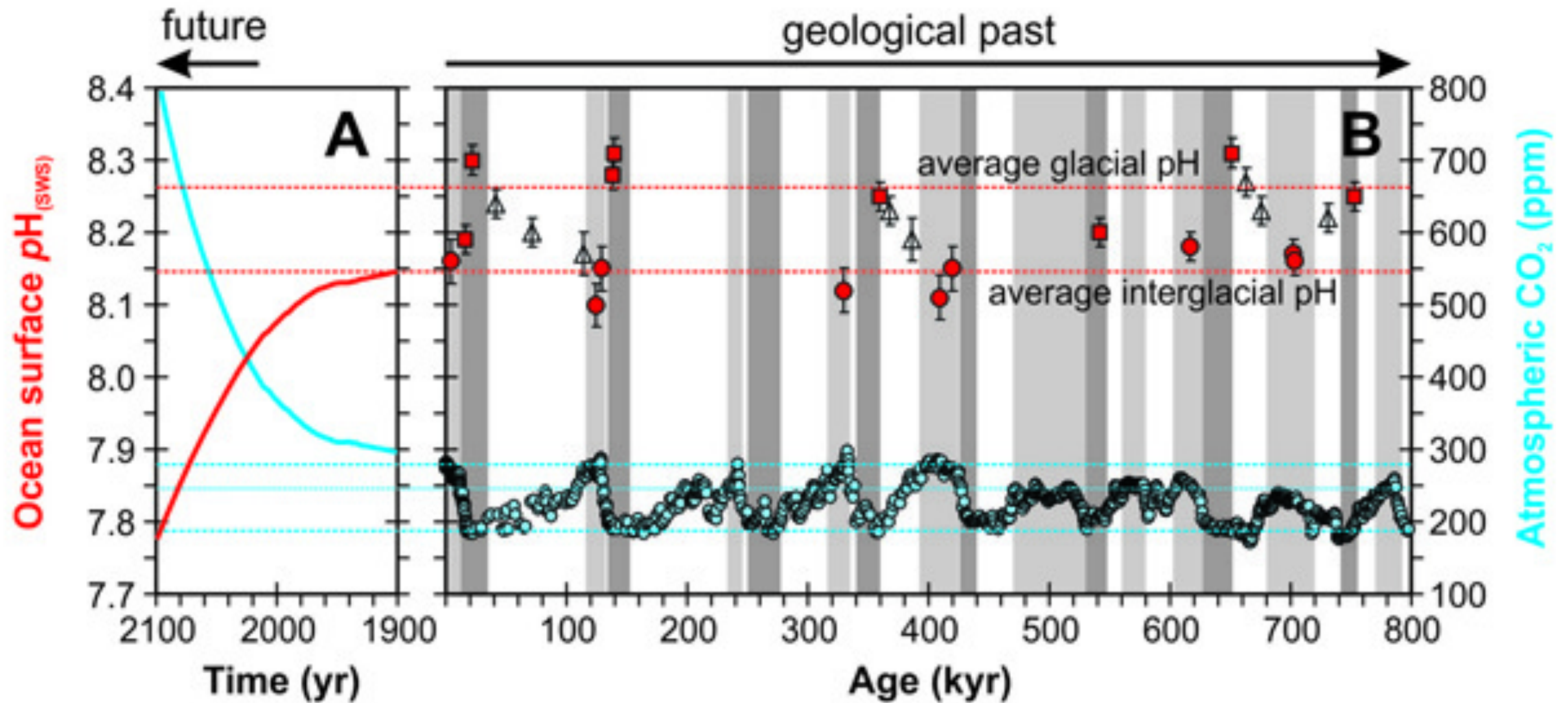
Laboratoire d'Océanographie de Villefranche (LOV)  
CNRS - Université Pierre et Marie Curie - Paris 6  
Villefranche-sur-mer, France

# Time-series of ocean acidification



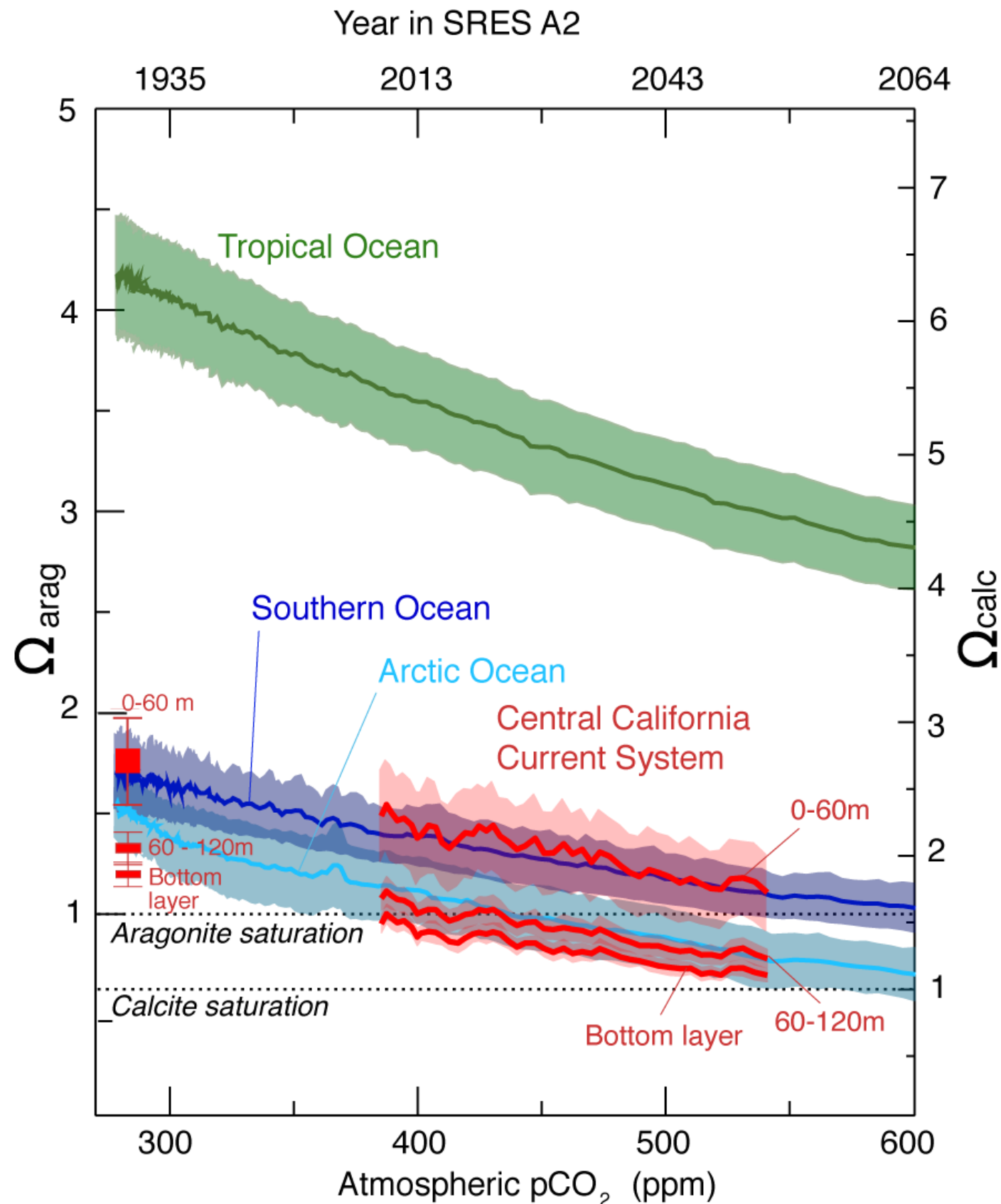
Orr (2011)

# Long-term perspective



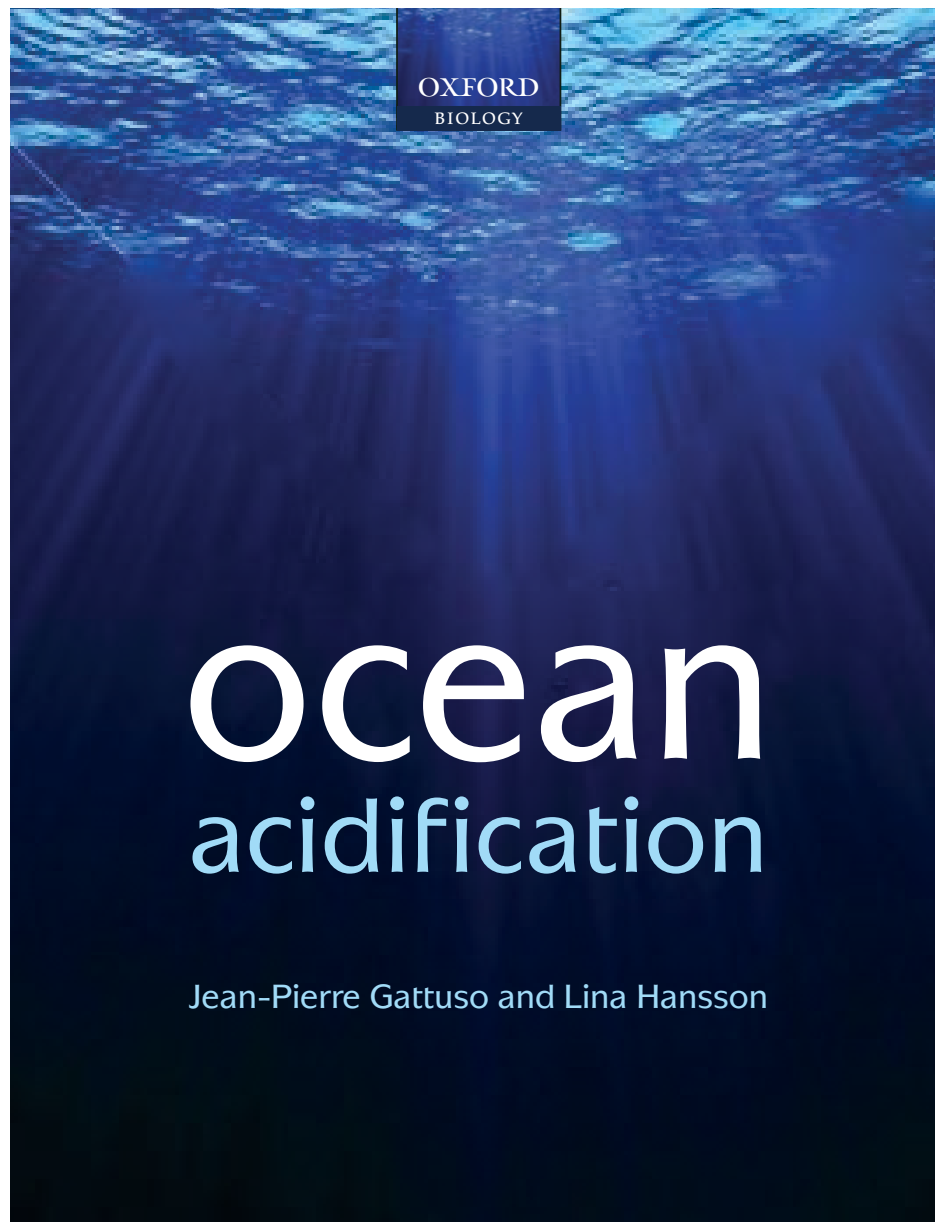
Barker & Ridgwell (2012)

# Rapid progression of ocean acidification in the California Current System (EBUS)



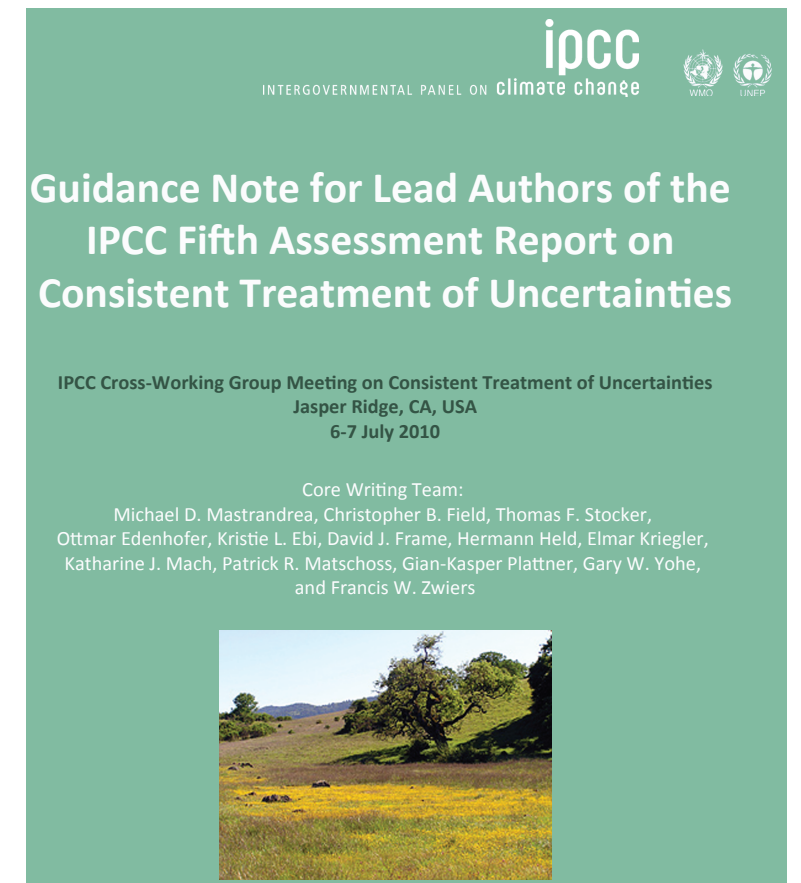
Gruber *et al.* (in press)

# Assessment



15 declarative statements  
assessed:

- Chemical aspects
- Biological and biogeochemical responses
- Policy and socio-economic aspects



Mastrandrea et al. (2010)

# Summary on statements

- **Chemical effects:** robust evidence and high certainty
- **Biological and ecological effects:** much less certain
  - calcification, primary production, nitrogen fixation and biodiversity will be altered but with an unknown magnitude
  - some cannot be assessed
- **Biogeochemistry, society and the economy** may change; whether it will be significant or not is also unknown

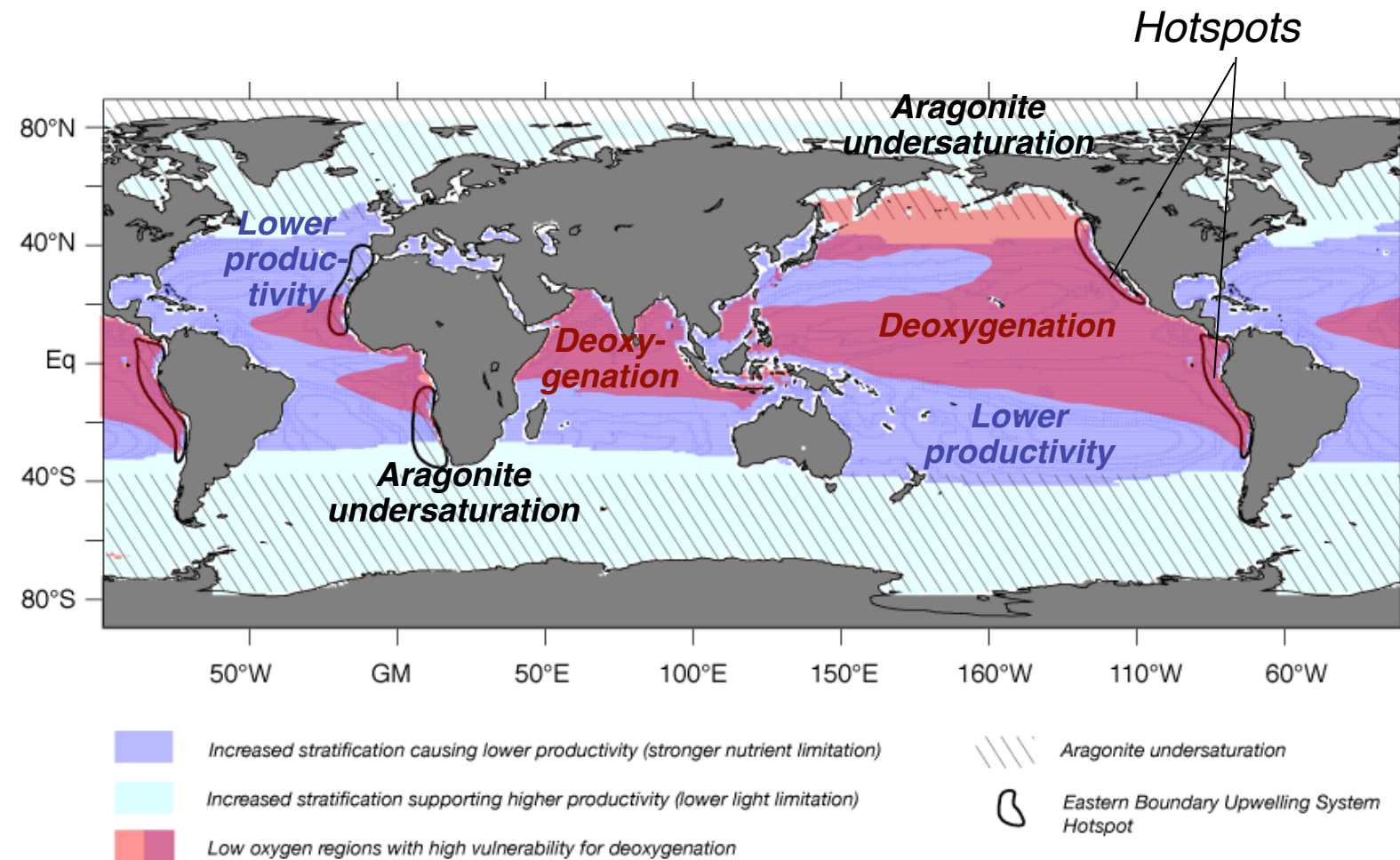
# Systems at risk

- Polar areas
- Deep-sea environments
- Coral reefs
- Nearshore ecosystems



# Warming up, turning sour, losing breath: ocean biogeochemistry under global change

- OA not acting in isolation
- Warming increases oxygen loss and stratification (deoxygenation)
- Warming, acidification, and deoxygenation in 21st century
- Only begun to fathom ecological and biogeochemical effects

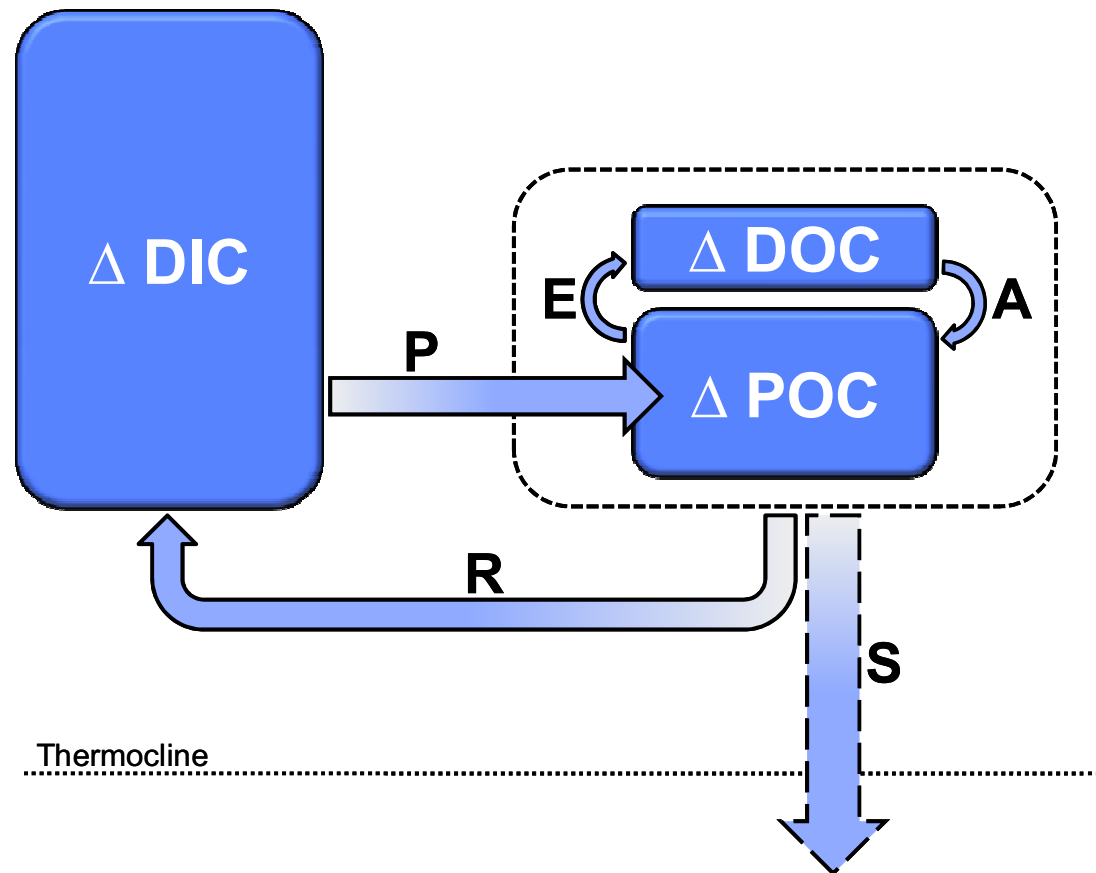


The triumvirate of ocean change (Gruber, 2011)

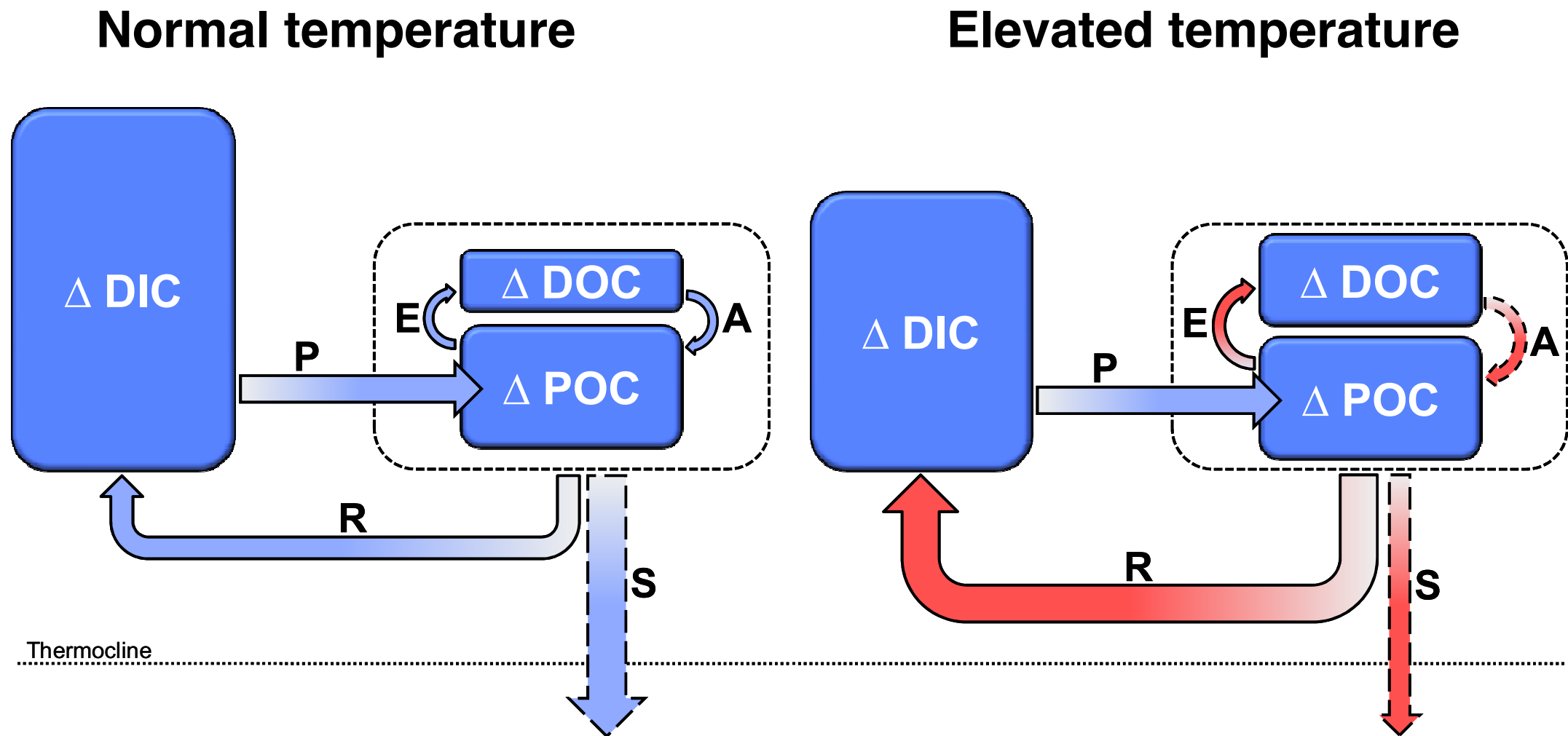


# Changes in biogenic carbon flow in response to sea surface warming

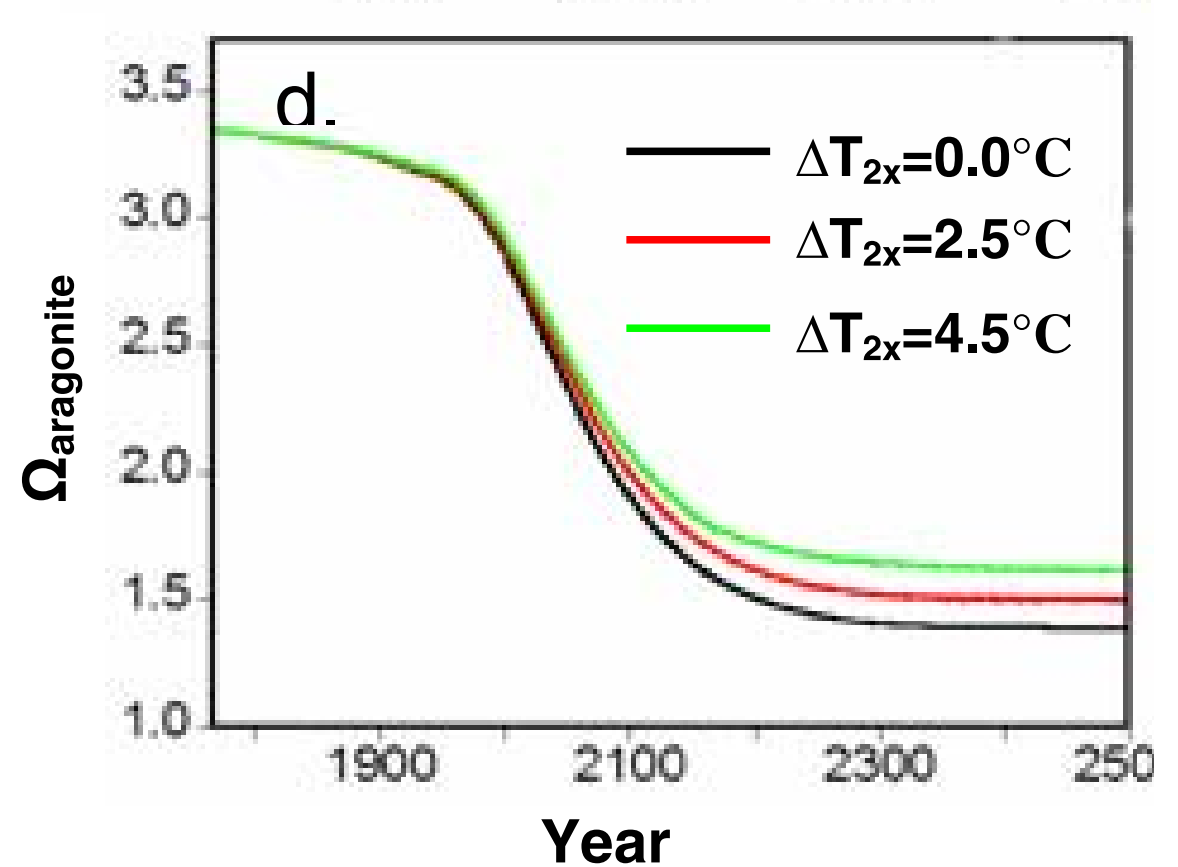
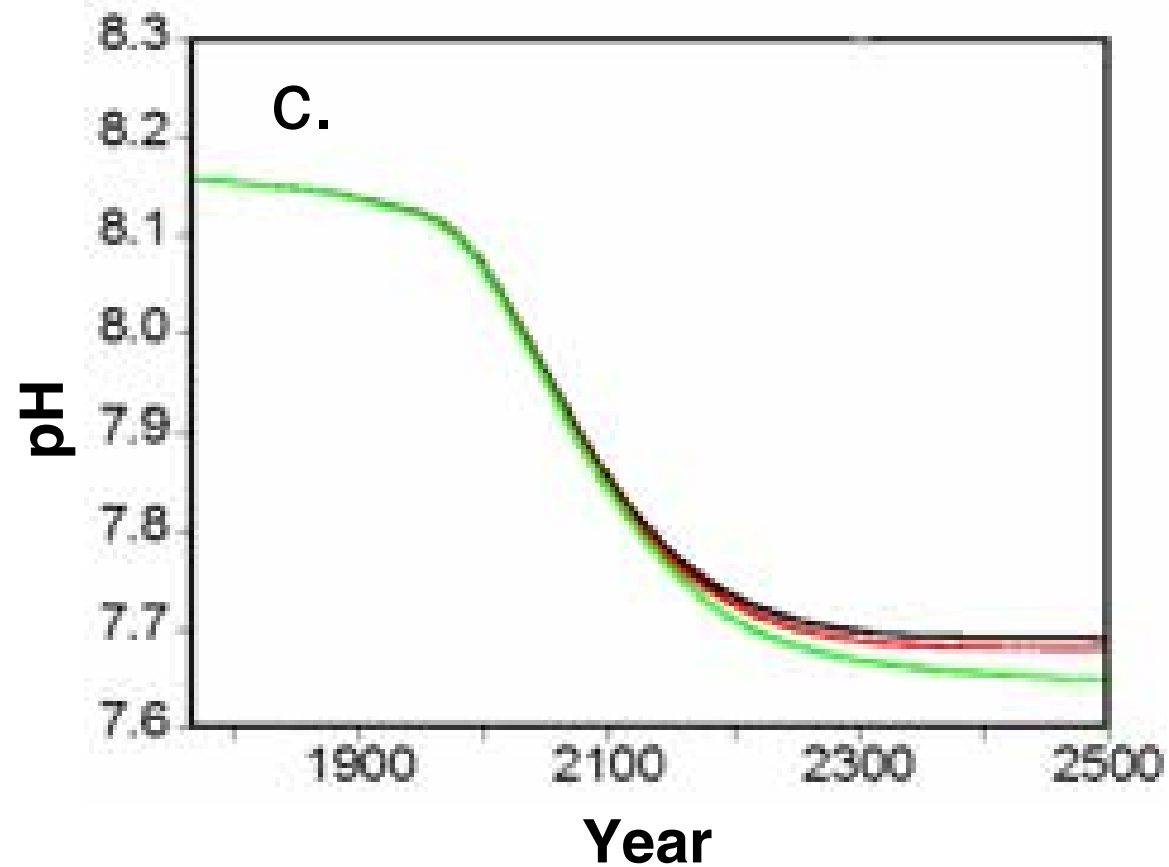
Normal temperature



# Changes in biogenic carbon flow in response to sea surface warming

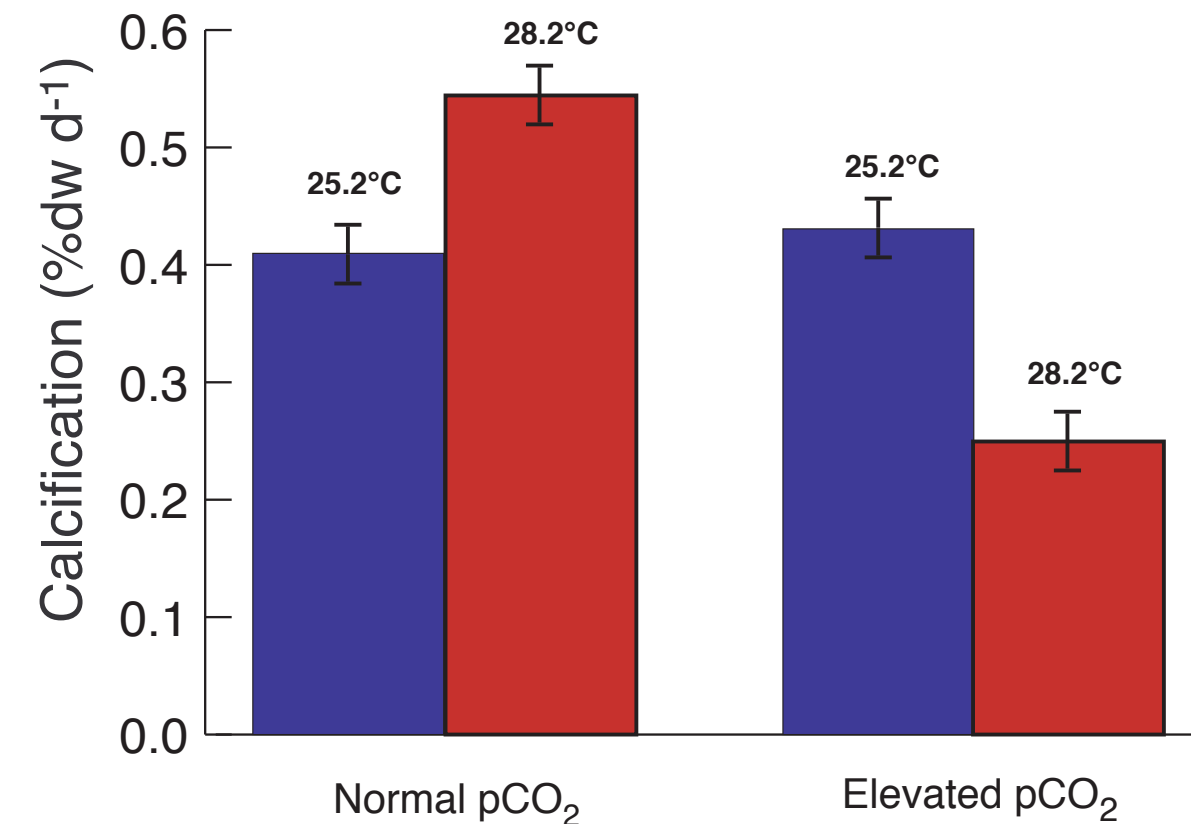


# Very limited impact of climate change on the carbonate system



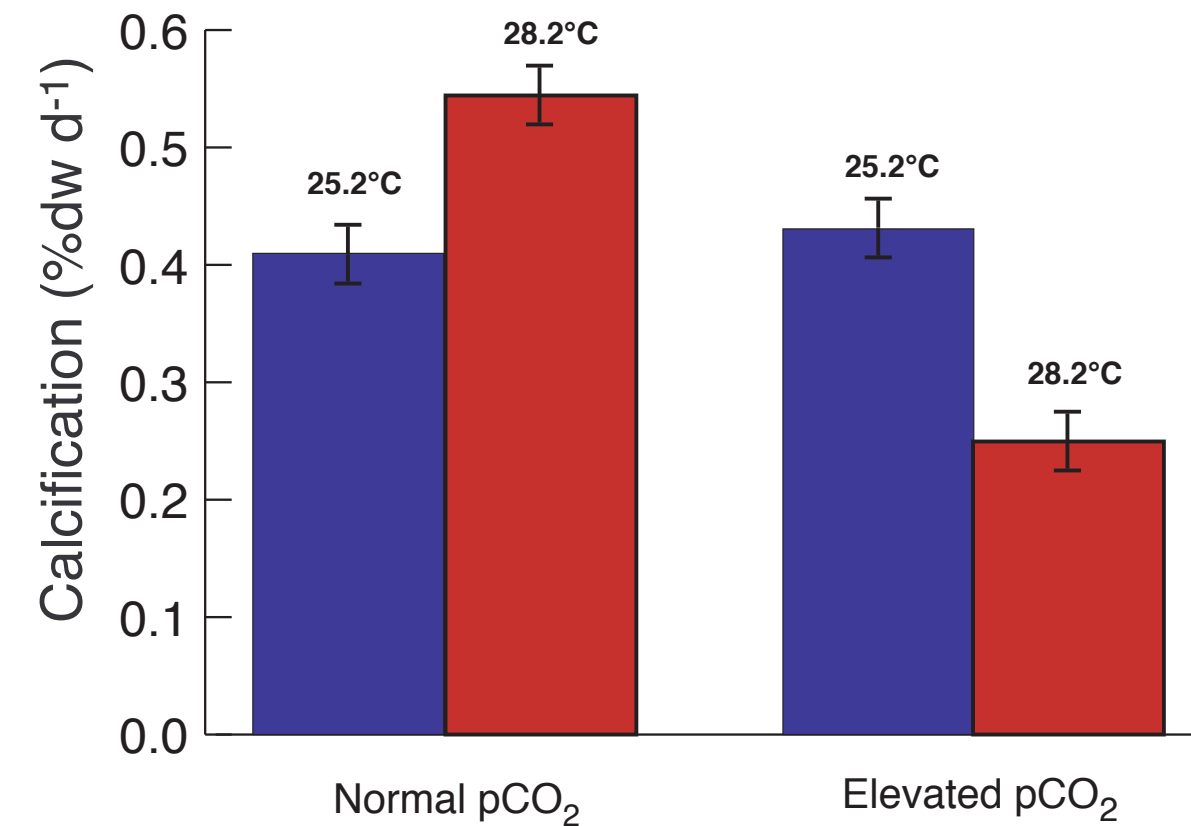
Cao *et al.* (2007)

# Interaction between ocean warming and acidification

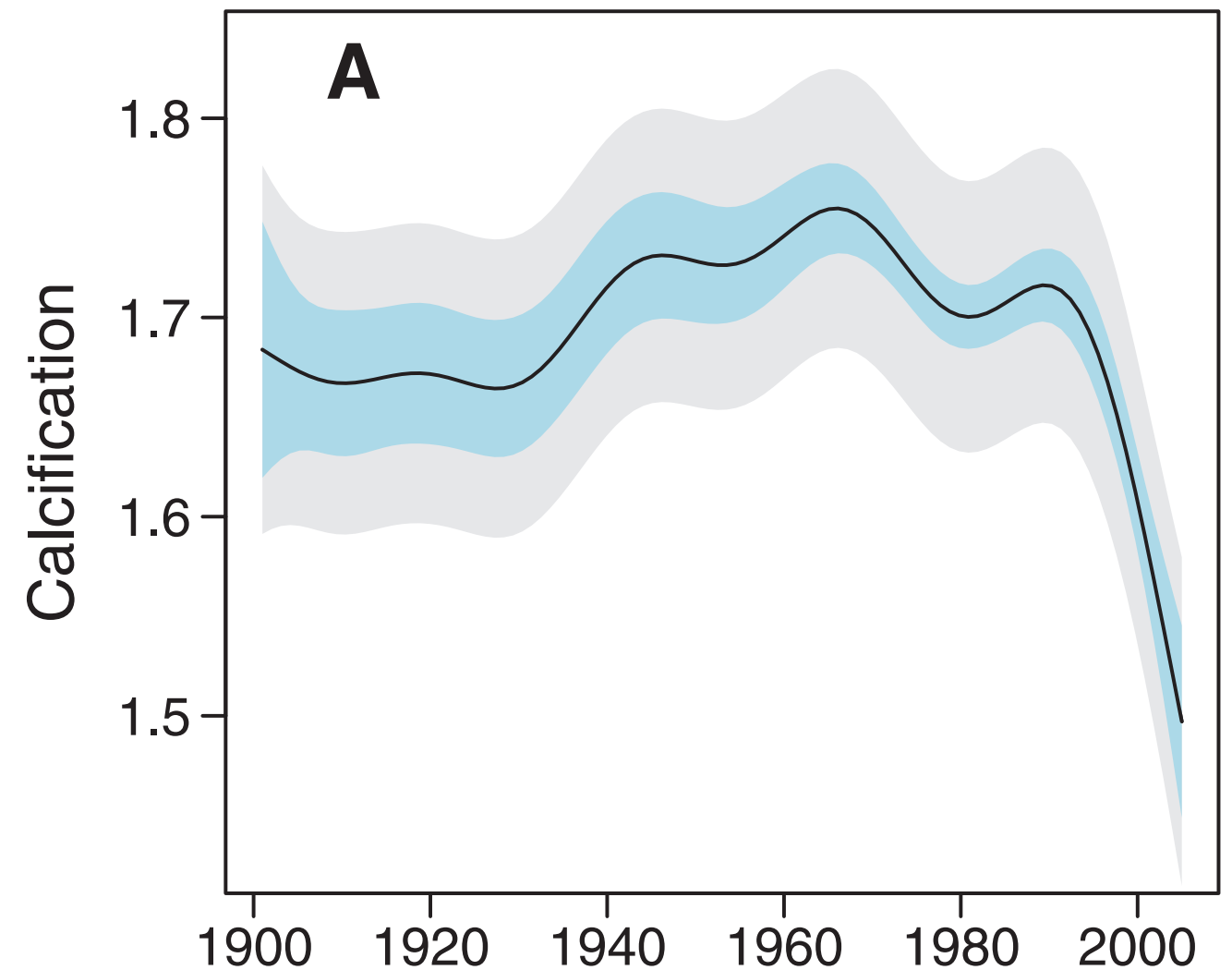


Coral perturbation experiments  
(Reynaud et al., 2003)

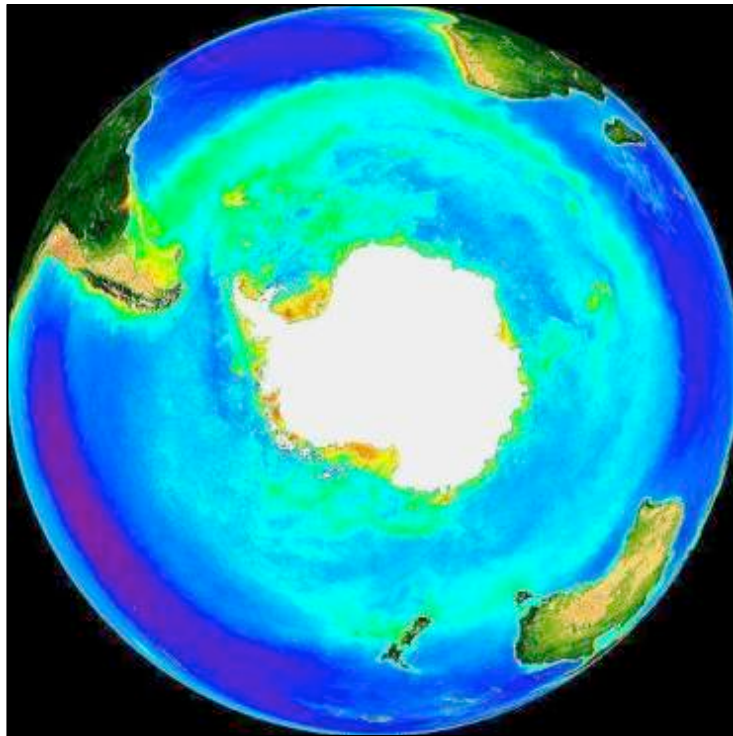
# Interaction between ocean warming and acidification



Coral perturbation experiments  
(Reynaud et al., 2003)



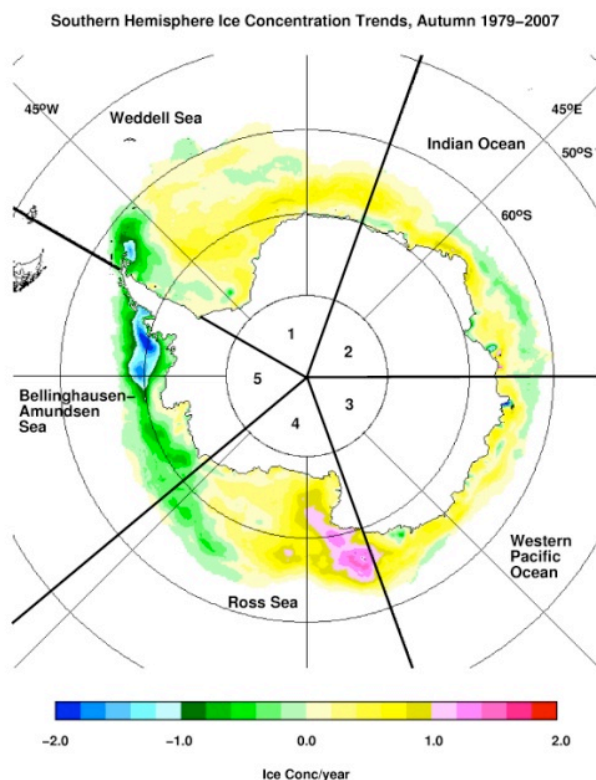
Reconstruction of coral calcification  
on the GBR (De'ath et al., 2011)



# Changes -> possible changes?

## Ocean

Temperatures, frontal positions, circulation and connectivity, mixed layer depths, variability (SAM, Ozone, Greenhouse?), eddies?



## Sea ice

Extent, timing, thickness, drift, variability

## Biogeochemistry

CO<sub>2</sub>, upwelling, iron inputs, pH?

