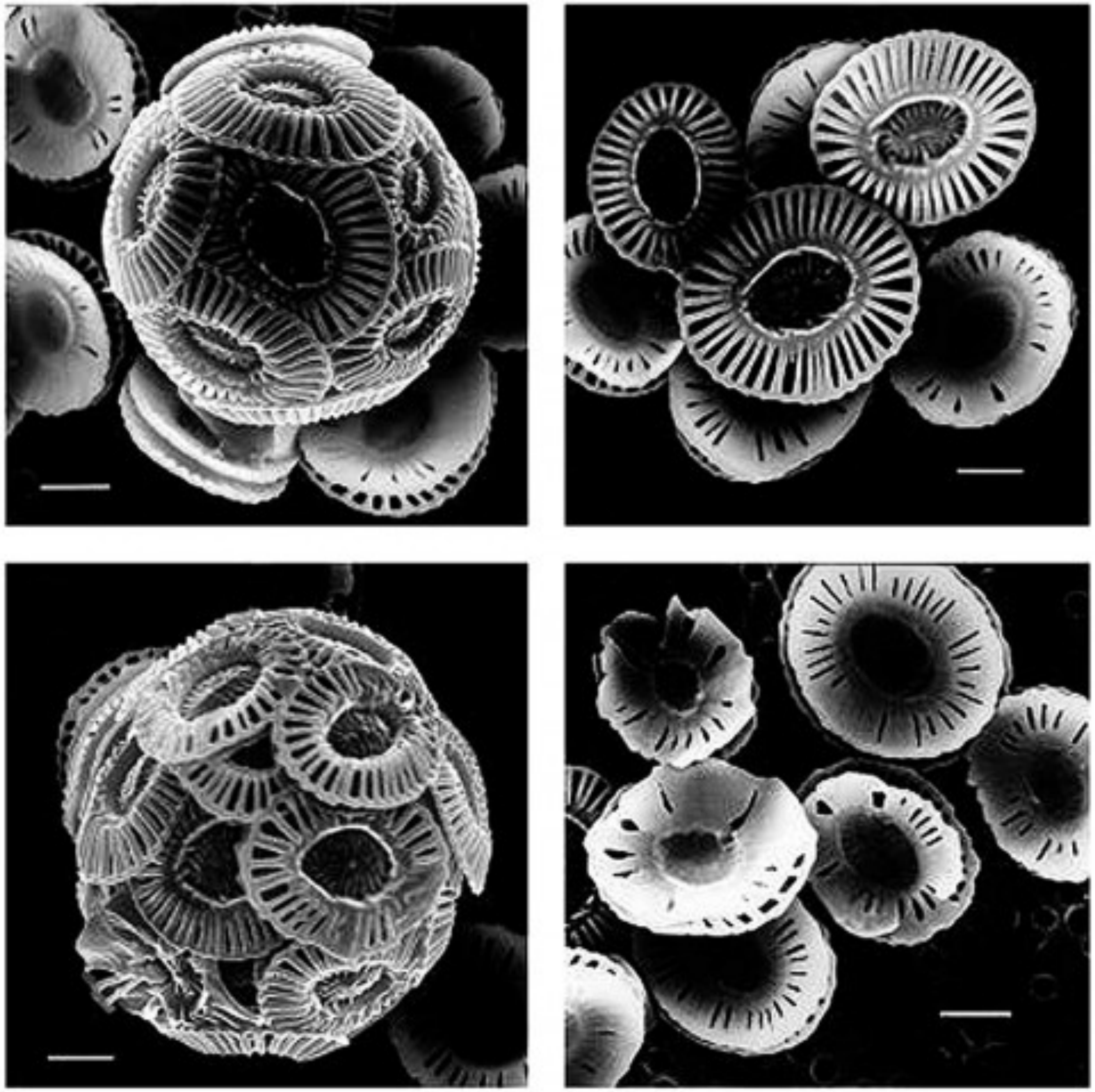
Ocean Acidification: past analogies, present concerns, future predictions

Scott Wieman

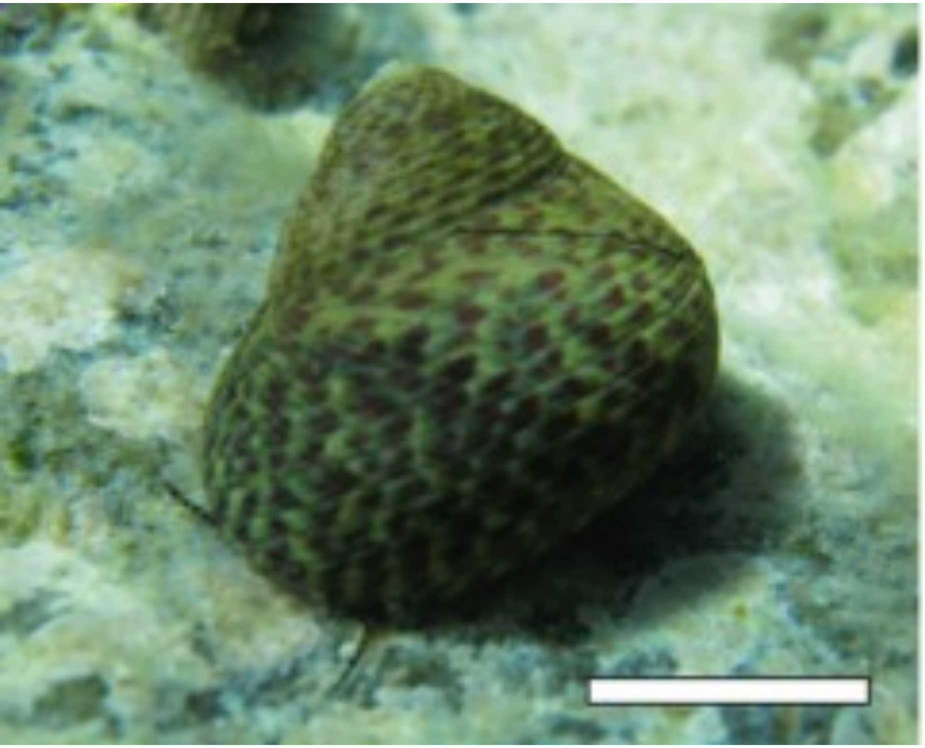
Effects

- Planktonic calcification
- Carbon and nutrient assimilation
- Primary production
- Acid-base balance
- Larval stages of higher trophic levels

Effects



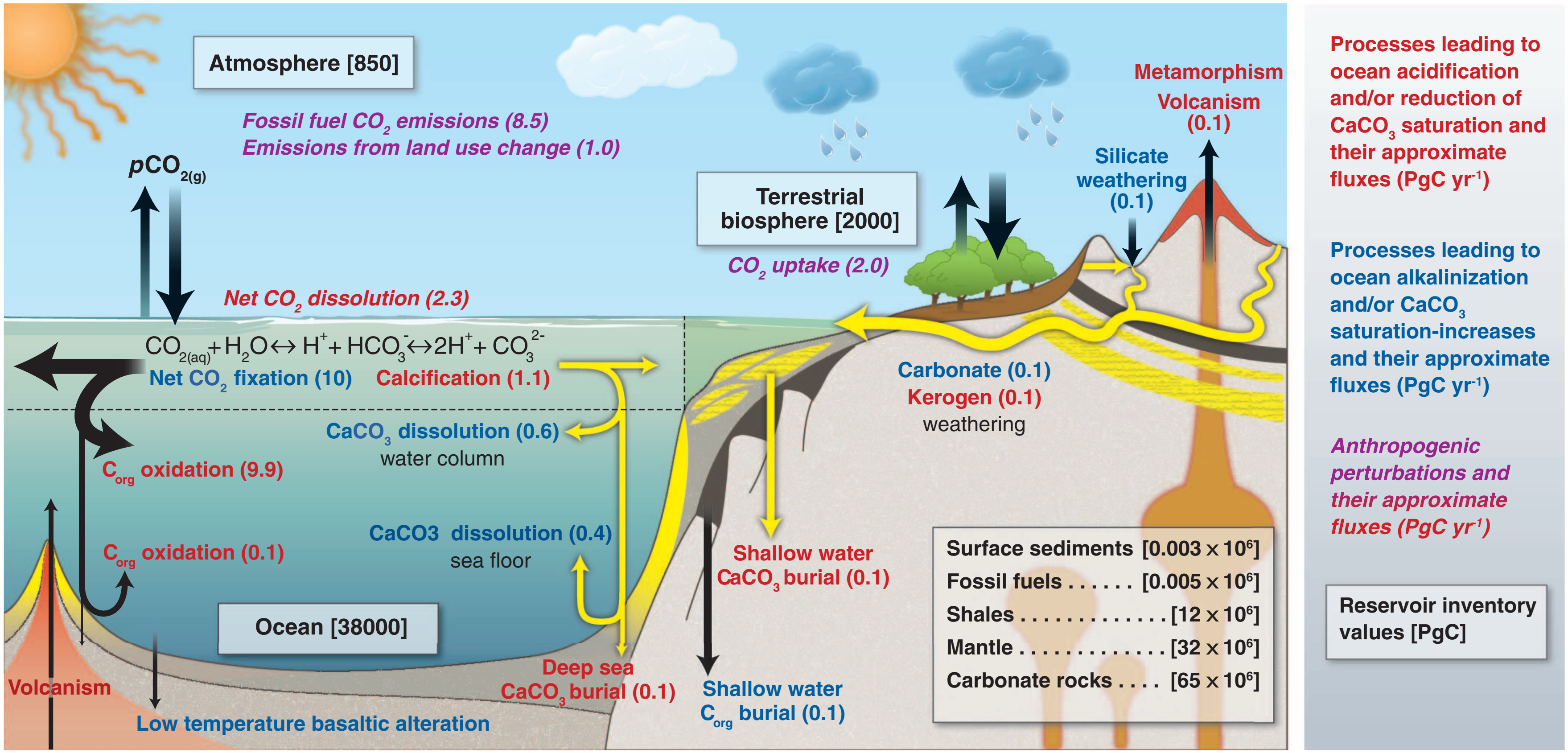
Effects



Effects

Effects

Principles of Ocean Acidification



Hönisch et al. 2012

Terminology

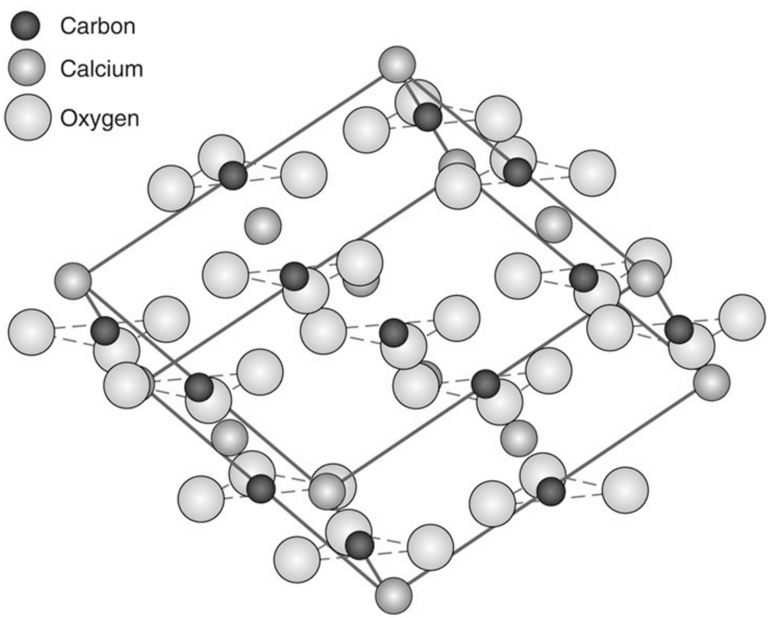
Ω=sat. state = $[Ca^{2+}]*[CO_3^{2-}]*(1/K_{sp})$

Precipitation is propotional to $(\Omega-1)^n$ for $\Omega>1$

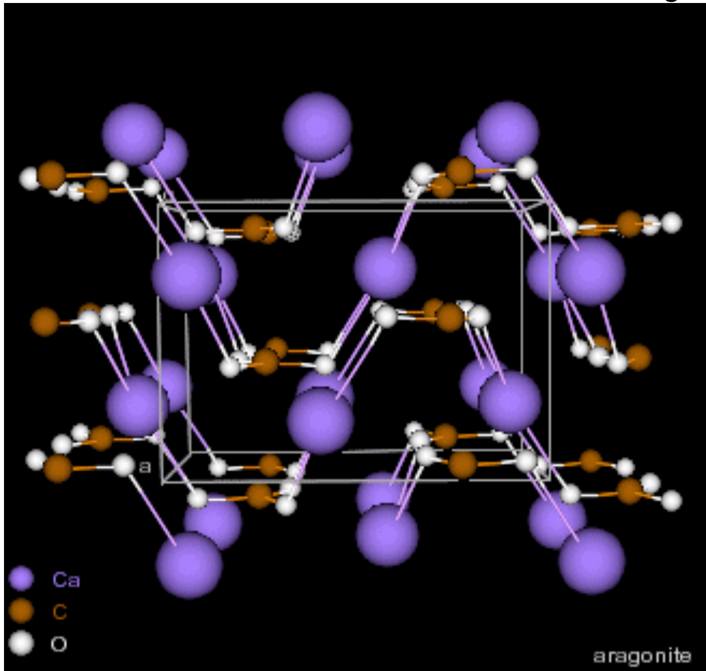
Dissolution is propotional to $(\Omega-1)^n$ for $\Omega<1$

$\Omega=1$ is the saturation horizon, Ω also defines the CCD

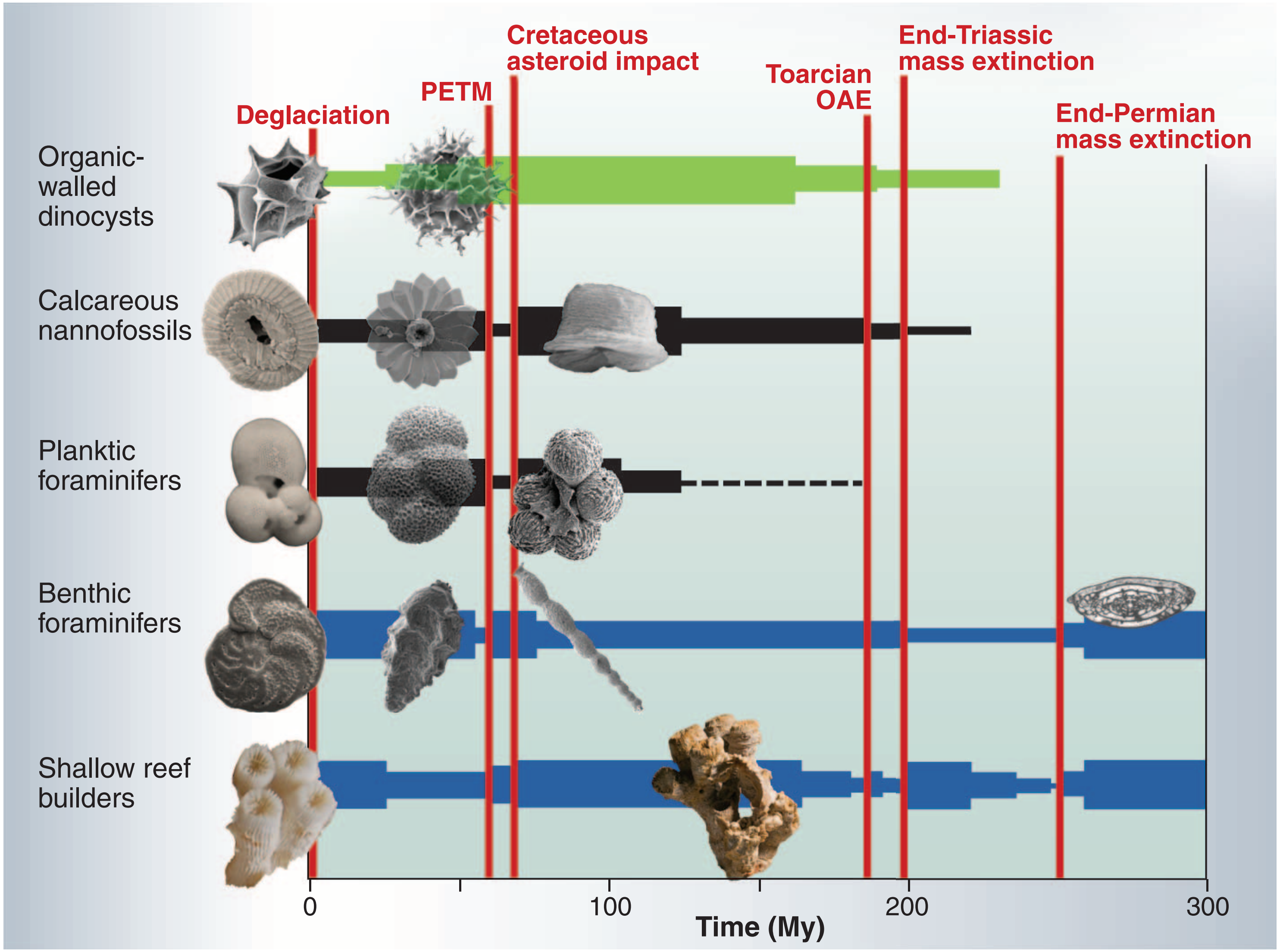
Calcite: trigonal $CaCO_3$



Aragonite: orthorhombic $CaCO_3$



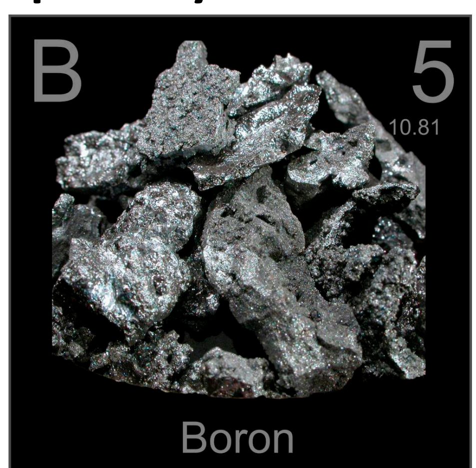
Broad Geologic Record



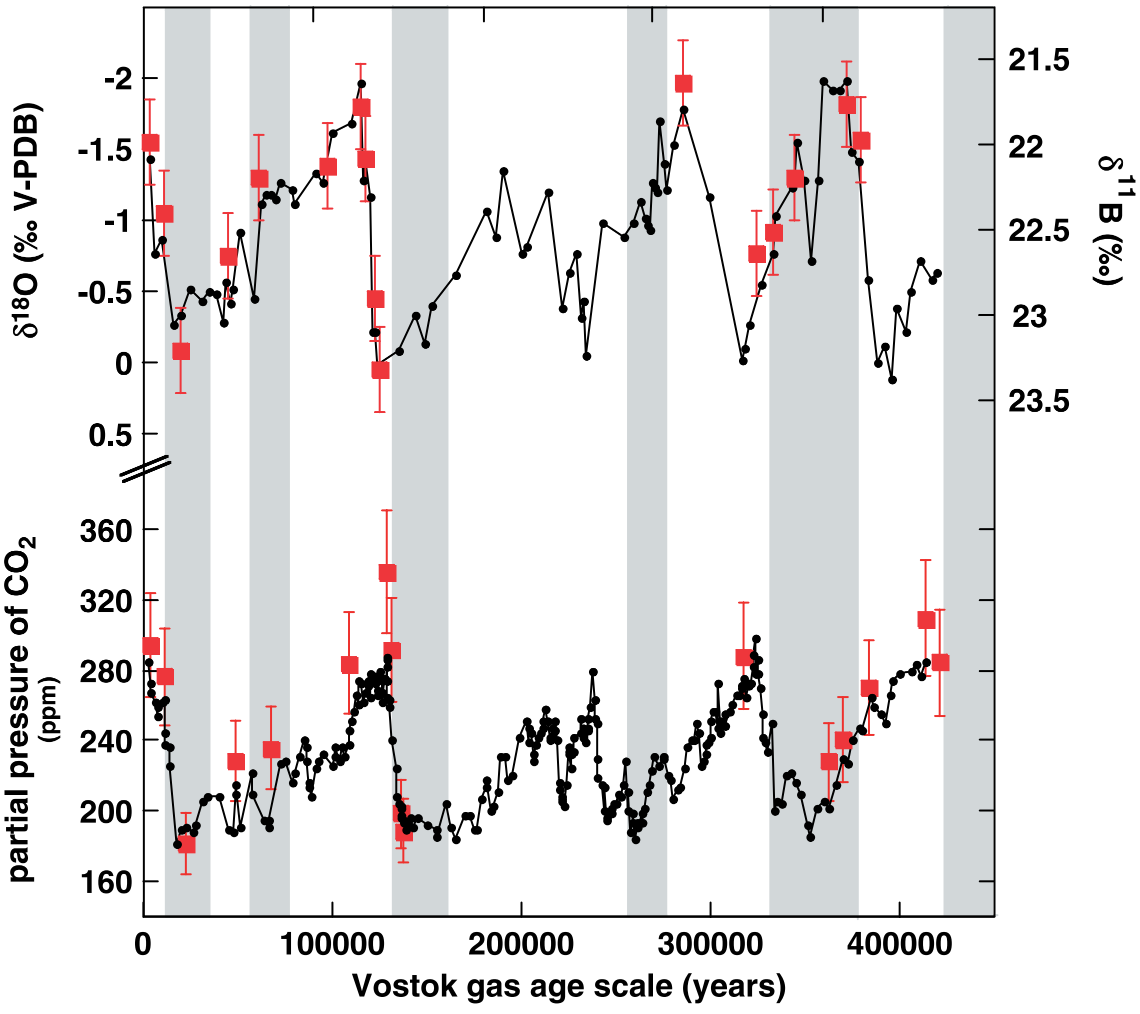
Hönisch et al. 2012

Boron-11 and pH/pCO_2

- Boron occurs as $B(OH)_4^-$ and $B(OH)_3$
- Relative concentrations pH dependent
- Only $B(OH)_4^-$ incorporated into shells
- $\delta^{11}B$ in forams records ocean acidity
- Also serves as a proxy for atmospheric pCO_2



Boron-11 and pH/pCO_2

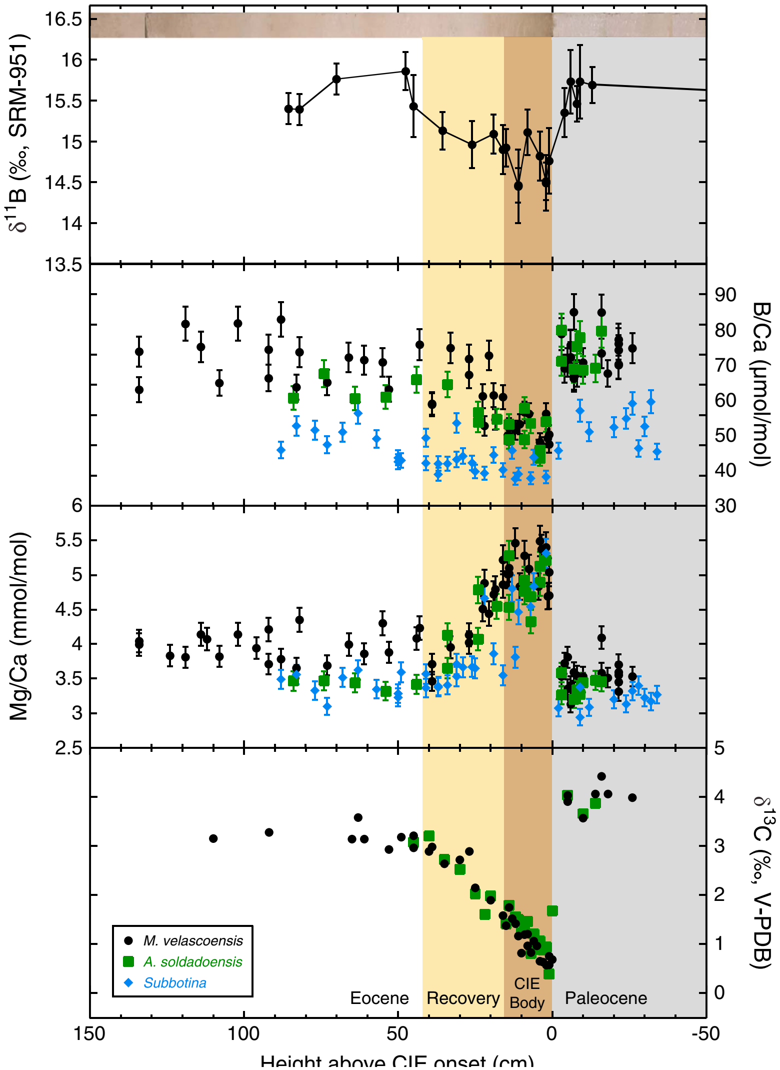


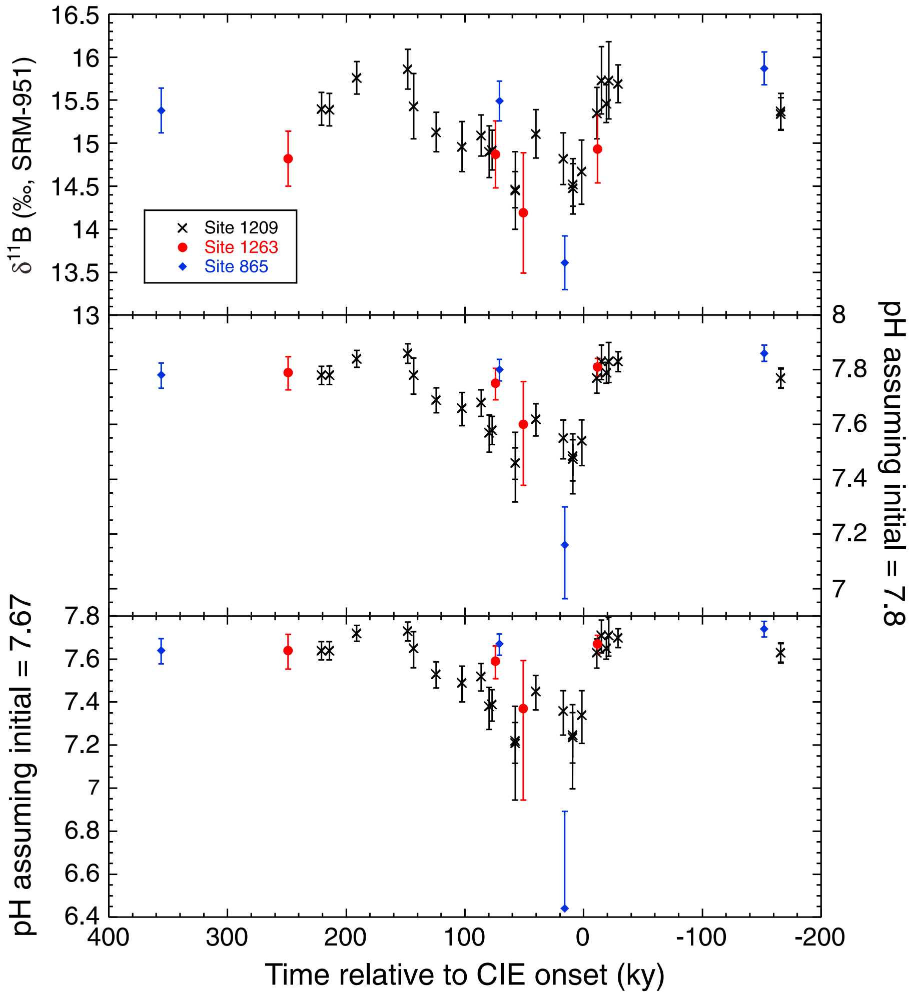
Hemming and Hönisch, 2007

The PETM

- 56 Mya
- 3-4‰ decrease in $\delta^{13}C$
- Rapid decrease in $CaCO_3$ content in organisms
- Transient warming of 4-8ºC
- Release of ~5000 Pg of C
- Significant surface acidification predicted
- Closest analogy to today (10x slower)

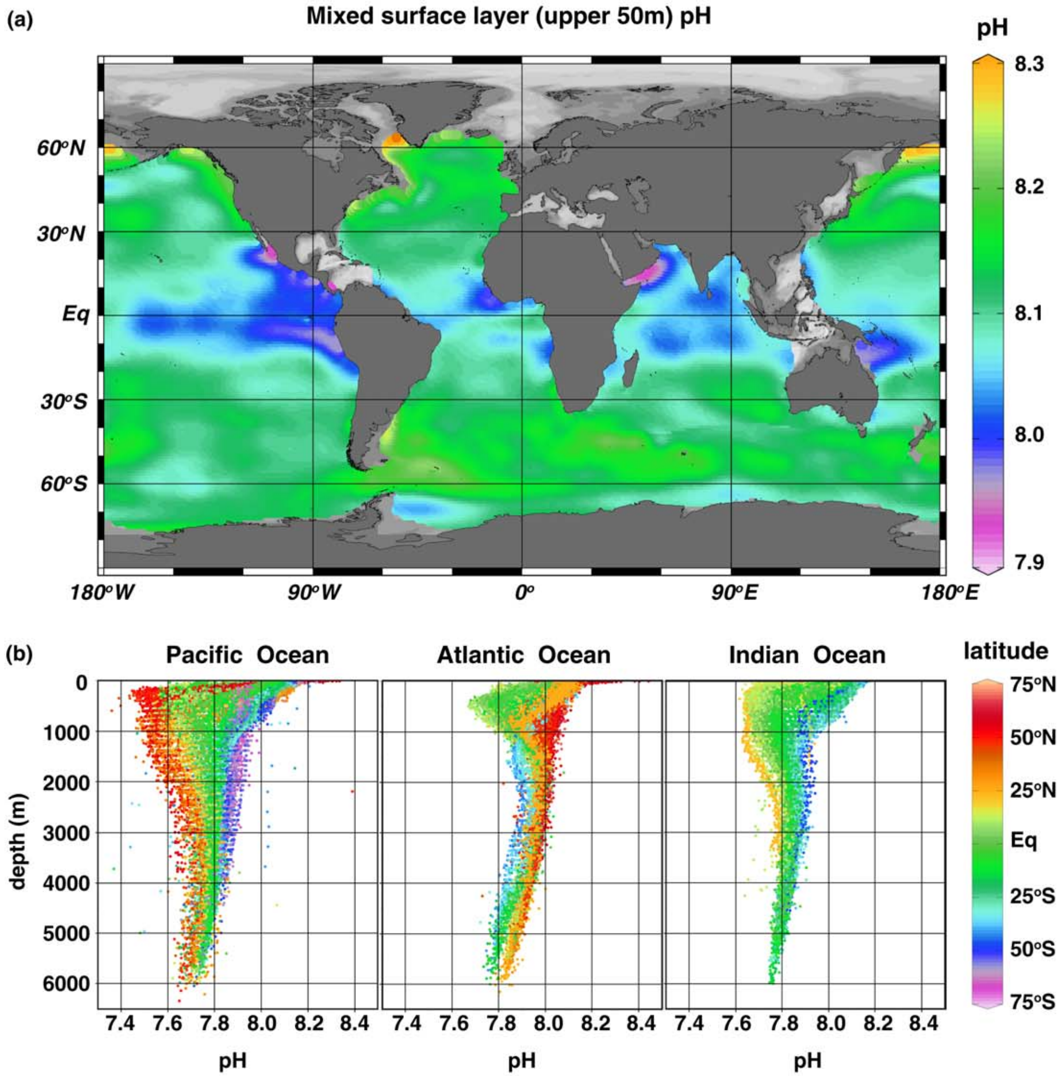
The PETM





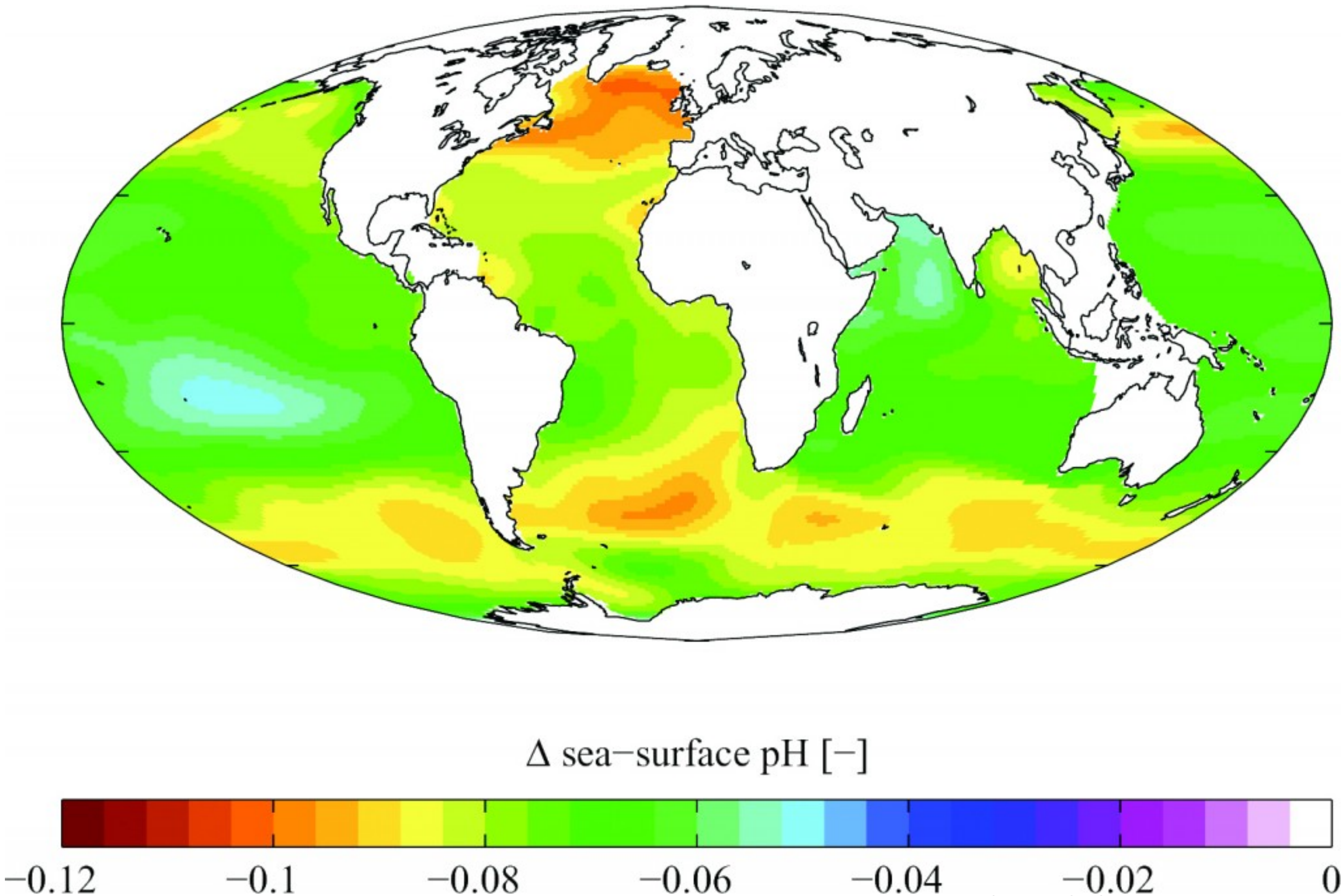
Penman et al., 2014

Present



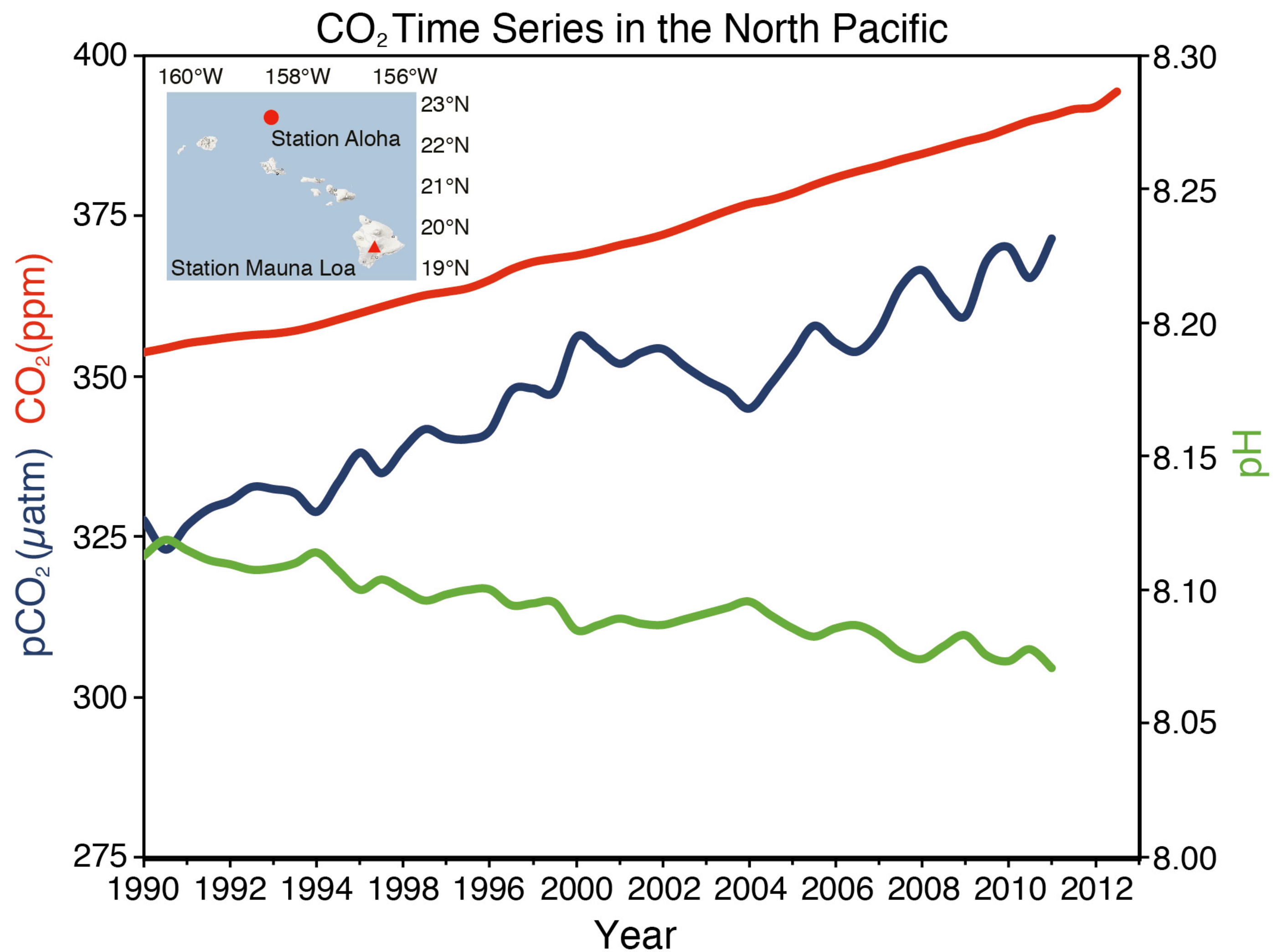
Pelejero et al., 2010

Change since Preindustrial



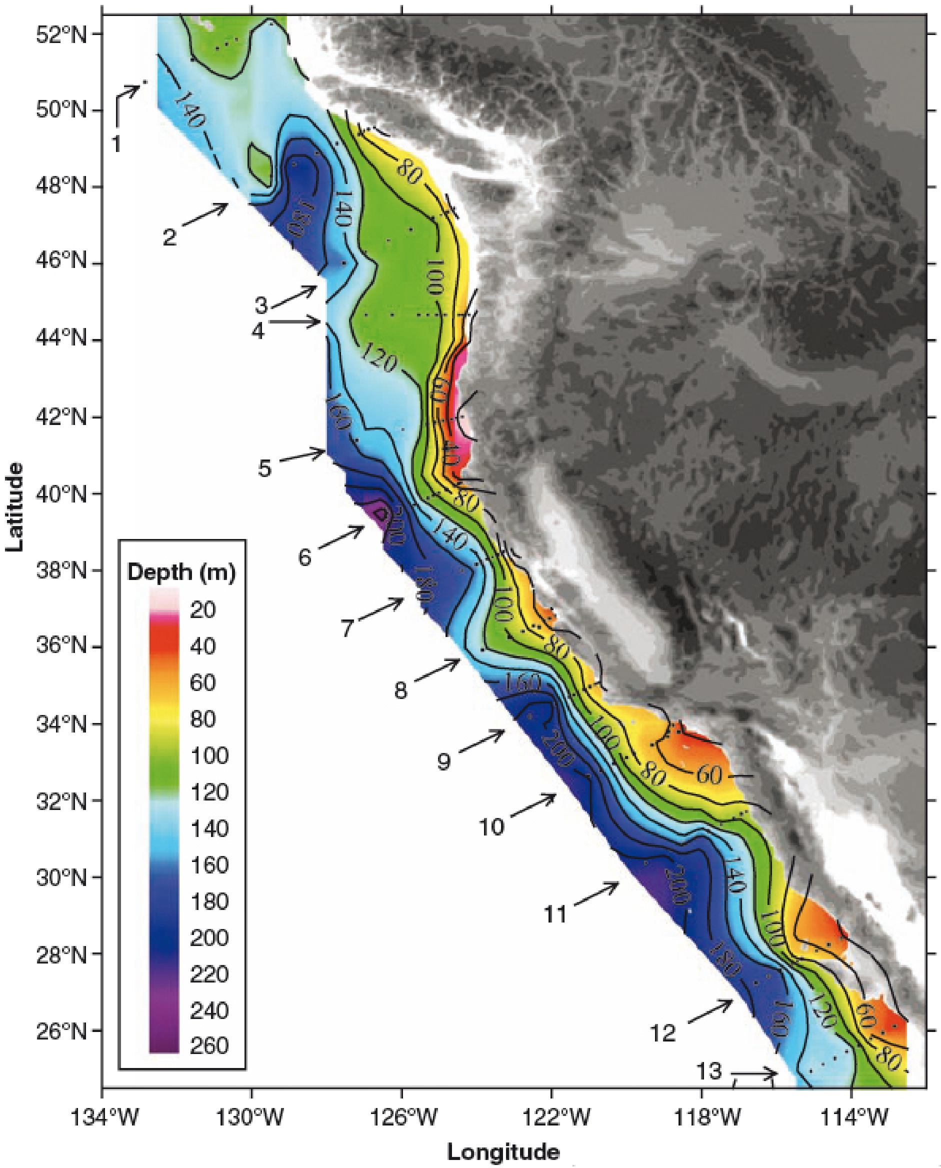
Högh-Guldberg and Bruno, 2010

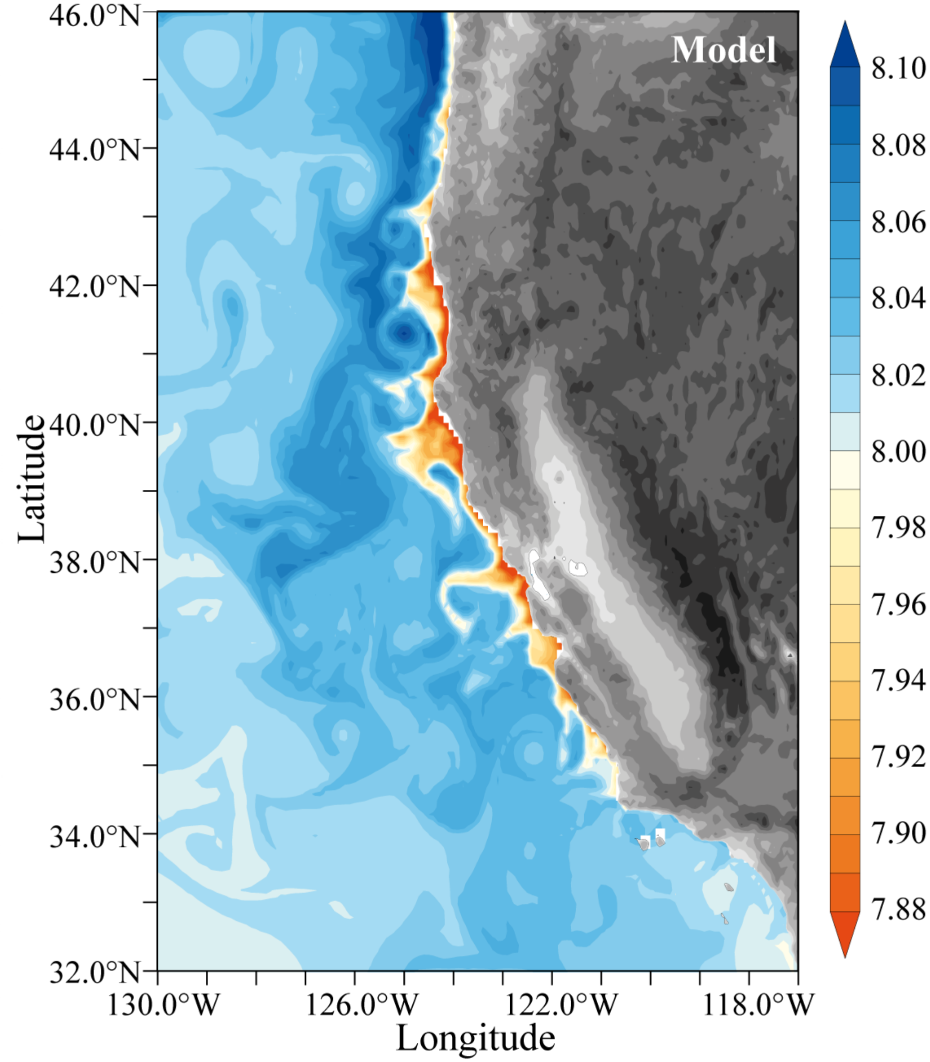
Recent past and Present



NOAA GFDL

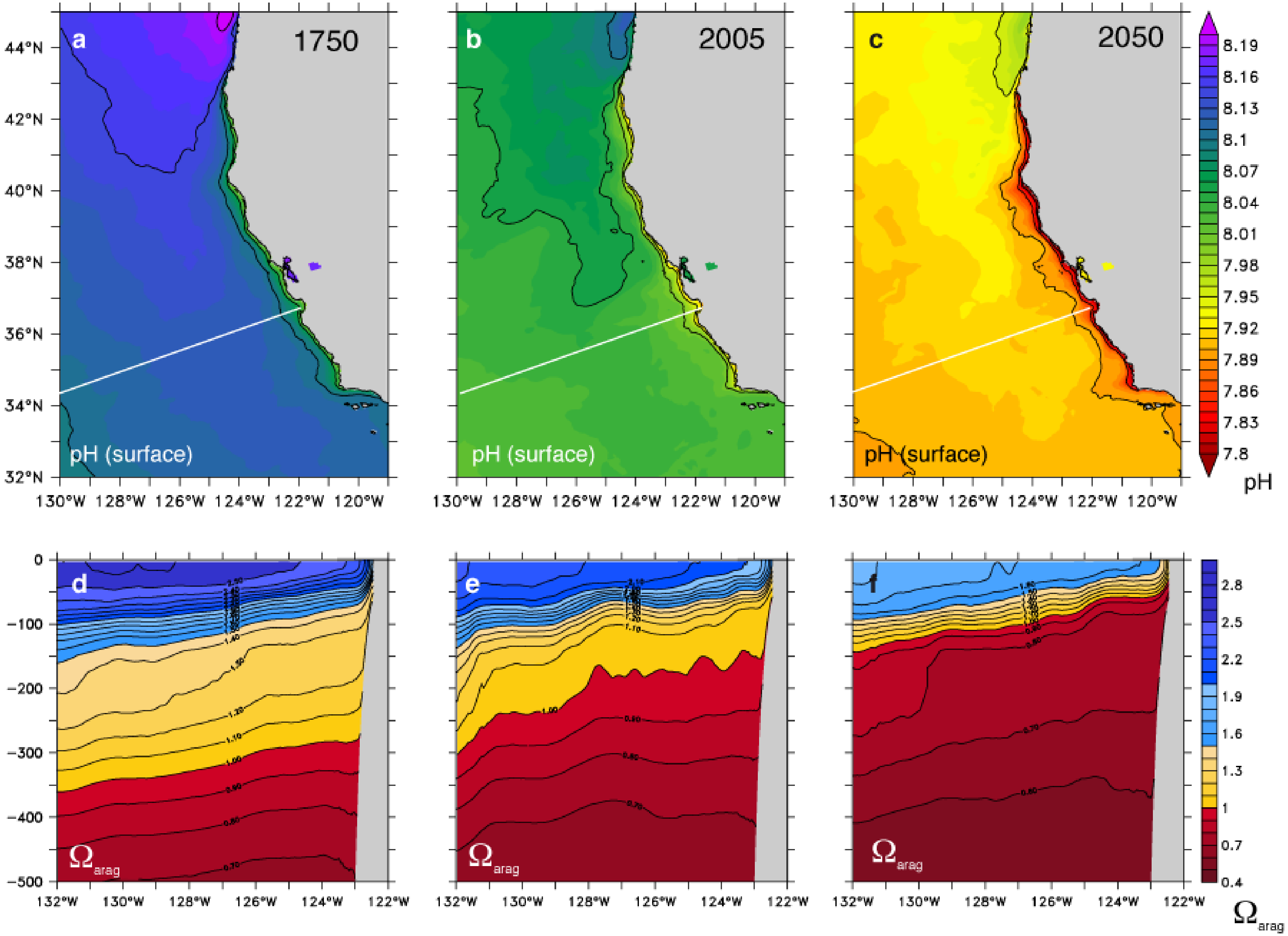
Recent past and Present





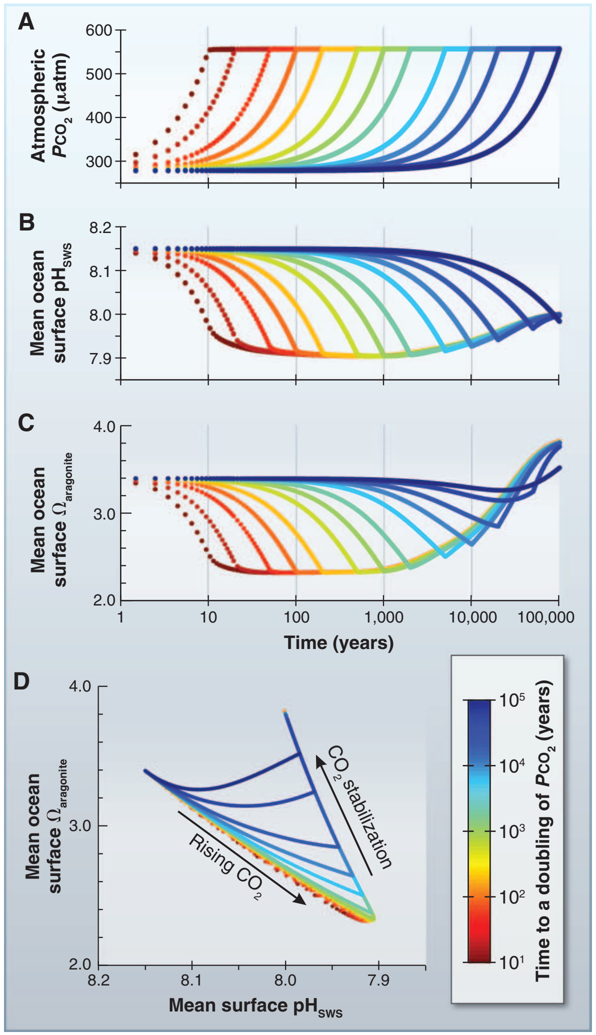
Feely et al. 2008

California Predictions



Gruber et al. 2010

Future Predictions



- Covarying factors
  - SST warming
  - Deoxygenation
- Integrated signal of coupled warming and acidification

Ridgwell and Zeebe, 2005

Future Predictions

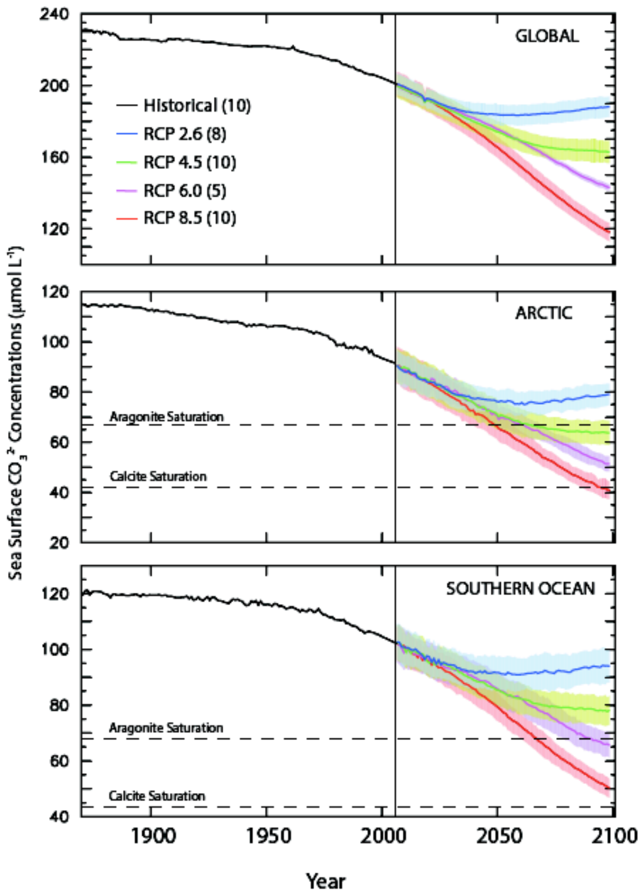


Fig. 7. Model-mean time series of mean surface carbonate ion concentrations ($\mu mol\,L^{-1}$) for the global ocean, the Arctic Ocean (north of 70° N), and the Southern Ocean (south of 60° S) over 1870–2100 using historical simulations as well as all RCP simulations. Also indicated are estimates of aragonite and calcite saturation levels for the Arctic and the Southern oceans (dashed lines).

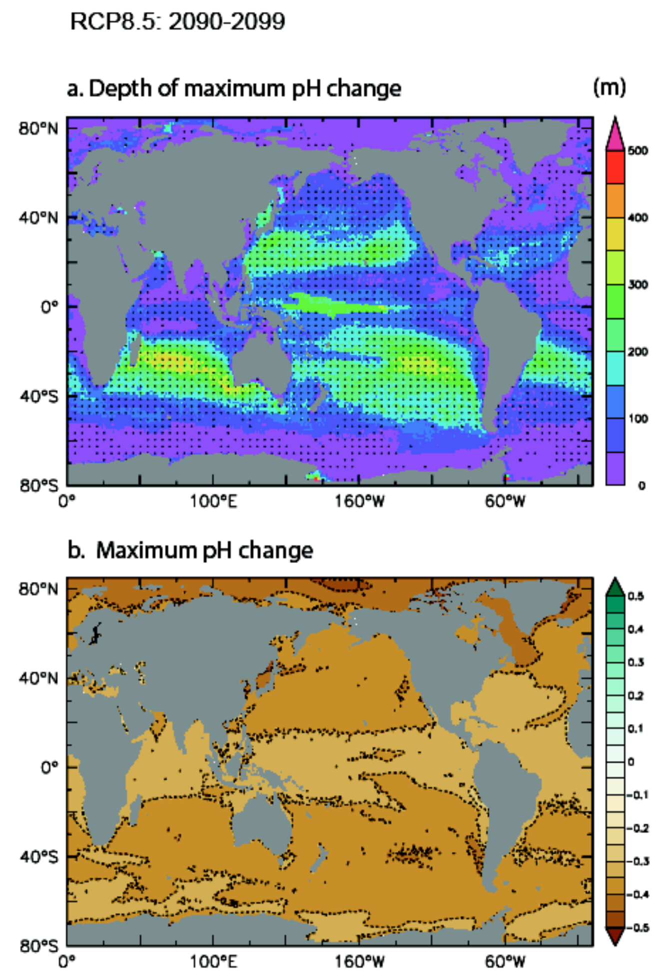


Fig. 8. Change in pH in 2090–2099 relative to 1990–1999 under RCP8.5. **(a)** Model-mean depth of the maximum changes in pH. Robustness estimated from inter-model standard deviation and **(b)** model-mean changes of pH at that depth.

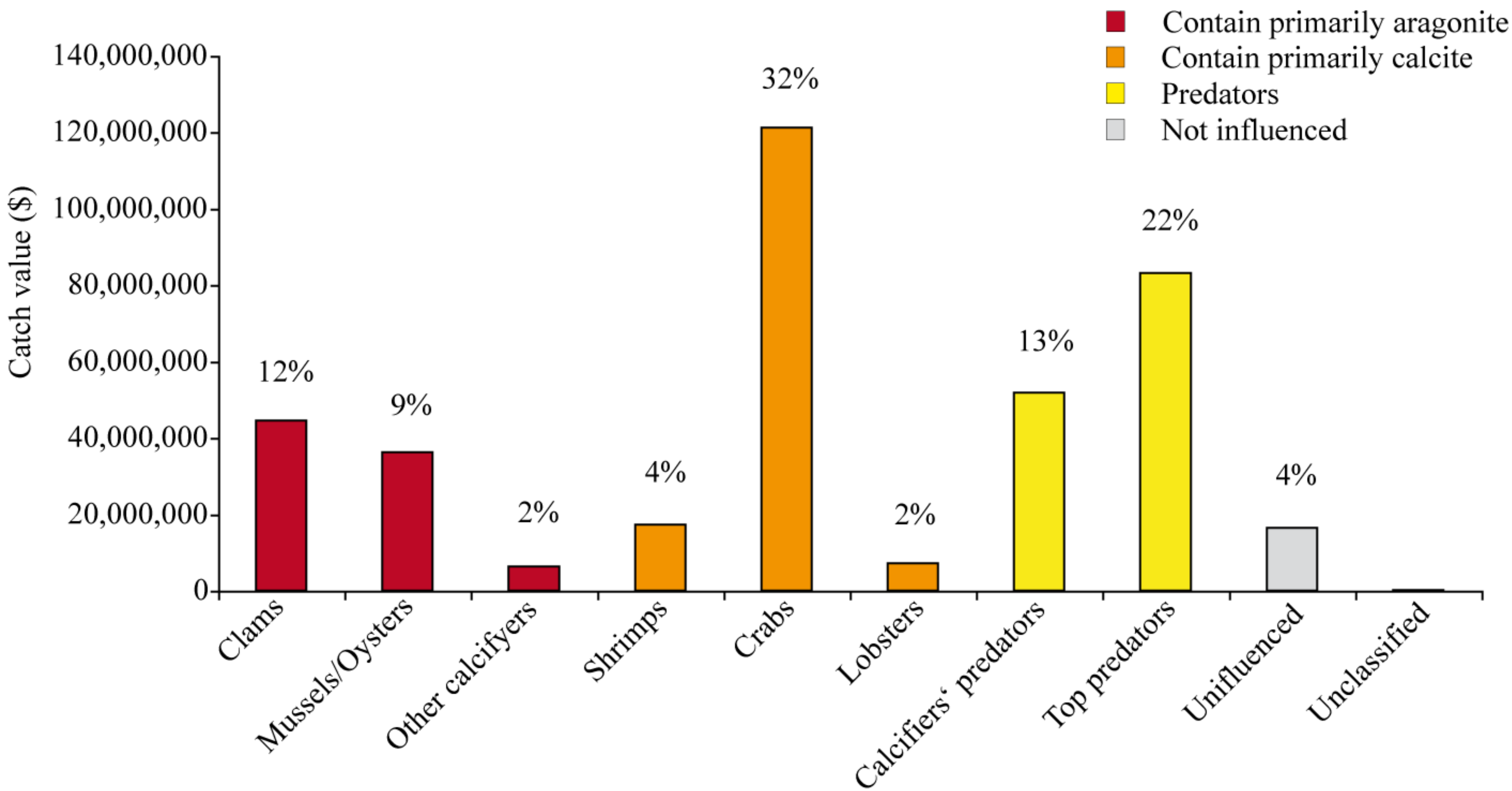
Acid Tolerance

	Average range
Marine Algae	6.8-9
Eelgrass	7.8-10.1
Molluscs	7.3-8.5
Arthropods	(4.7-7.4)-8.5
Cephalopods	6.0-9.5
Bony fishes	(4.5-6.5)-8.7

Corals vary greatly, some thrive in low-pH evnrionments (Palau) and others fail quickly

Locke, 2008

Economic Impact (USWC)



Hauri, 2012

The current rate of CO_2 release stands out as capable of driving a combination and magnitude of ocean geochemical changes potentially unparalleled in at least the last 300 My of Earth history, raising the possibility that we are entering an unknown territory of marine ecosystem change

Ridgwell and Zeebe, 2005

Mitigation

- Decrease carbon dioxide emissions.
- Anything that decreases atmospheric pCO_2

Mitigation

- Add powdered limestone to upwelling regions

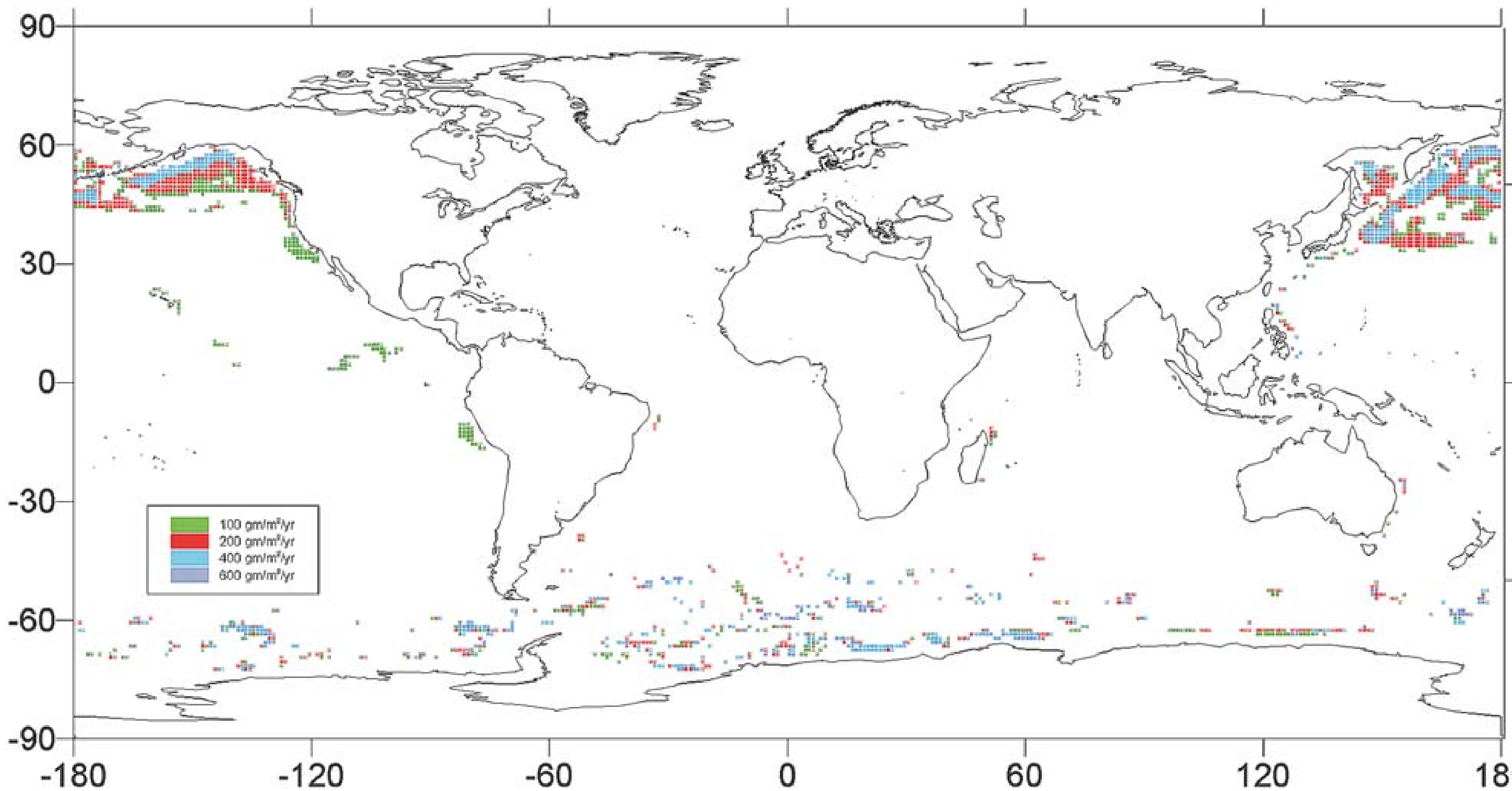


Figure 8. Distribution of the rate of addition of limestone powder (gm m^{-2} a^{-1}) that maximizes the total absorption of CO_2 in year 50, subject to a total application rate of 4 Gt a^{-1}.

Harvey, 2008

Variations on a theme

- Add fine silicate powders along coastlines
- Add calcite to unsaturated benthic regions

Boaty McBoatface 2016!