Ocean acidification and rates of change

SOS March 14, 2016

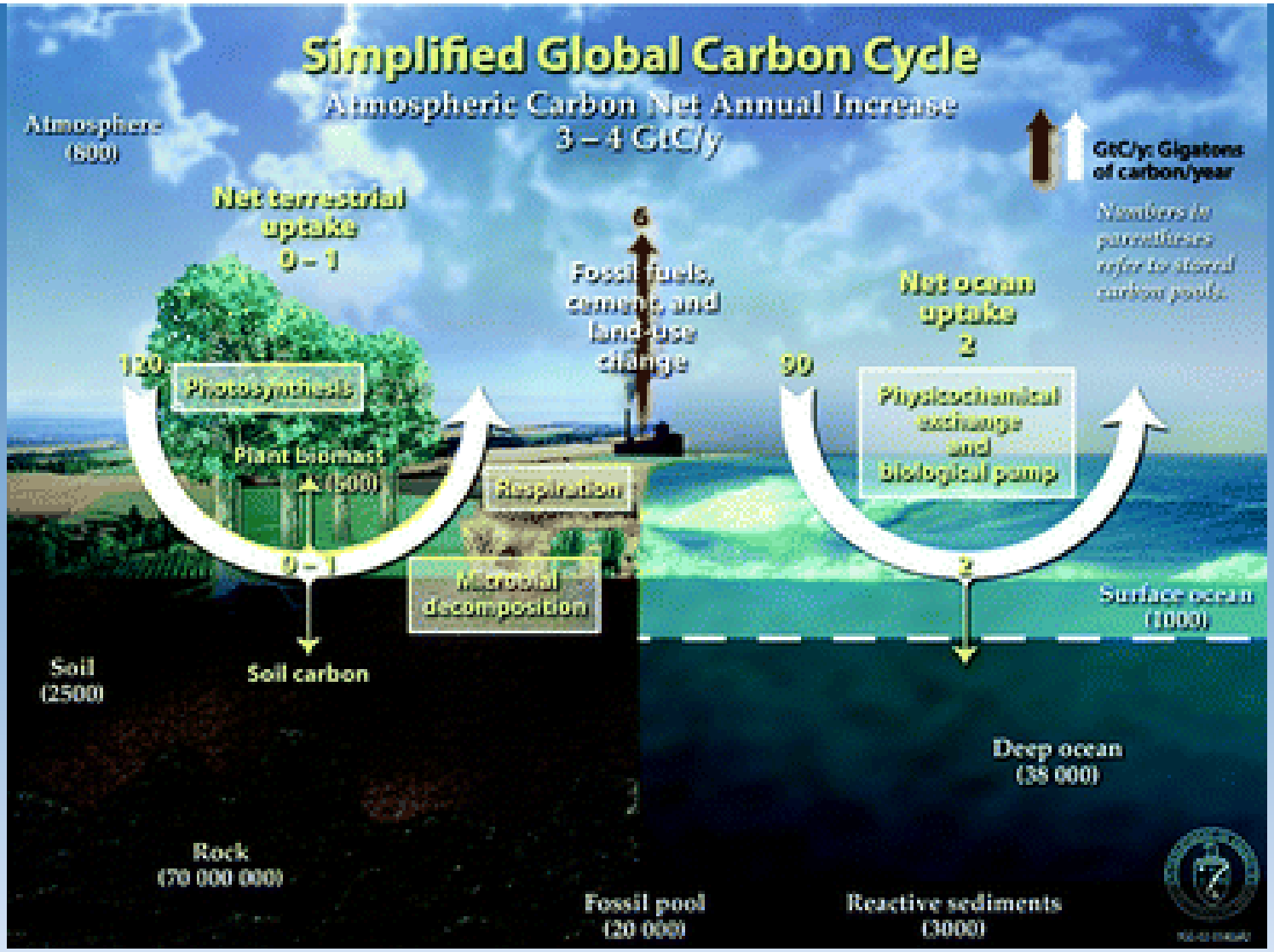
Paul Belanger

pebelanger@glassdesignresources.com; 303-249-7966

- **Ocean acidification**
- **Rates of change**

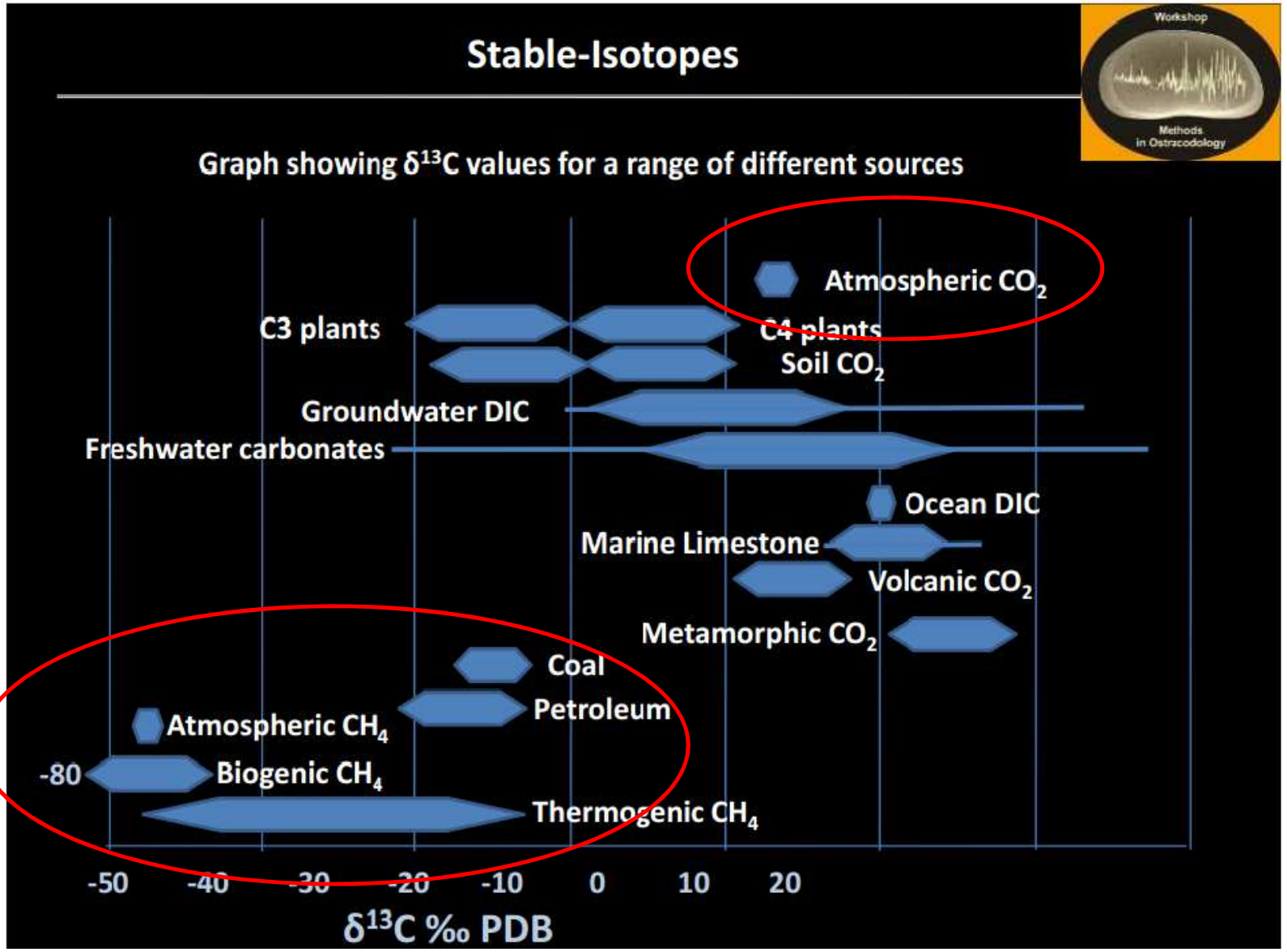
Ocean acidification

- Let's start with a video: https://youtu.be/W1TZ8g8JYVU from http://www.skepticalscience.com/ocean-acidification-global-warming.htm



http://www.pmel.noaa.gov/co2/story/Ocean+Carbon+Uptake

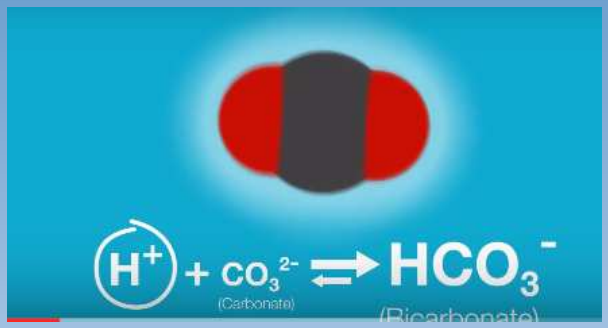
Stable-Isotopes



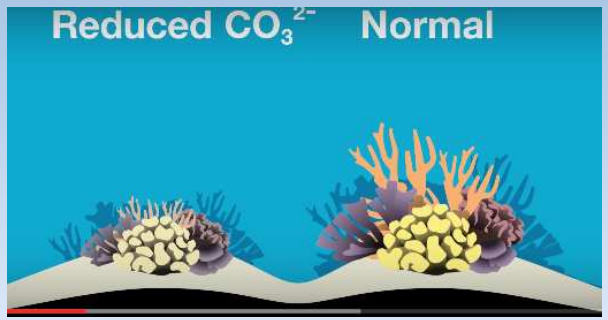
VIDEO HIGHLIGHTS: Ocean acidification

- Adding CO_2 adds H^+ ions making water more acidic (lowers pH)

- This in turn reduces CO_3^{-2} ions



- reducing CO_3^{-2} makes it more difficult for organisms to make their shell – especially aragonitic ones



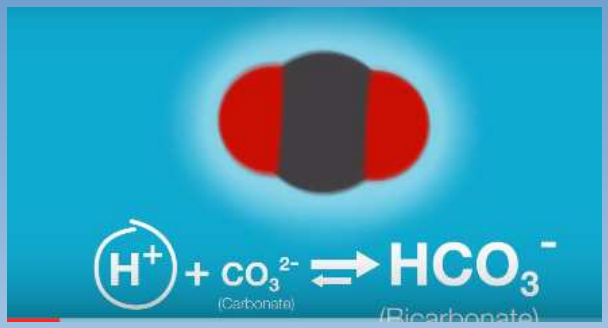
http://www.skepticalscience.com/ocean-acidification-global-warming.htm

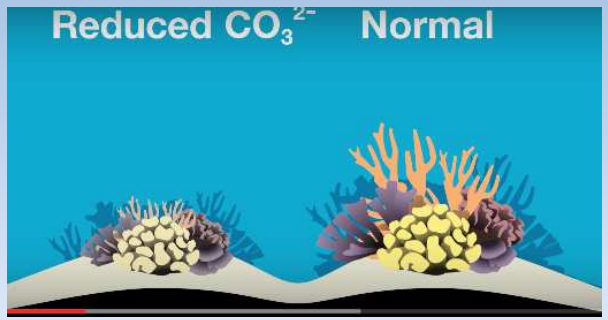
Continued

- Takes hundreds of years to equilibrate from weathering – or buffering from the deep sea carbonates as we saw in the PETM

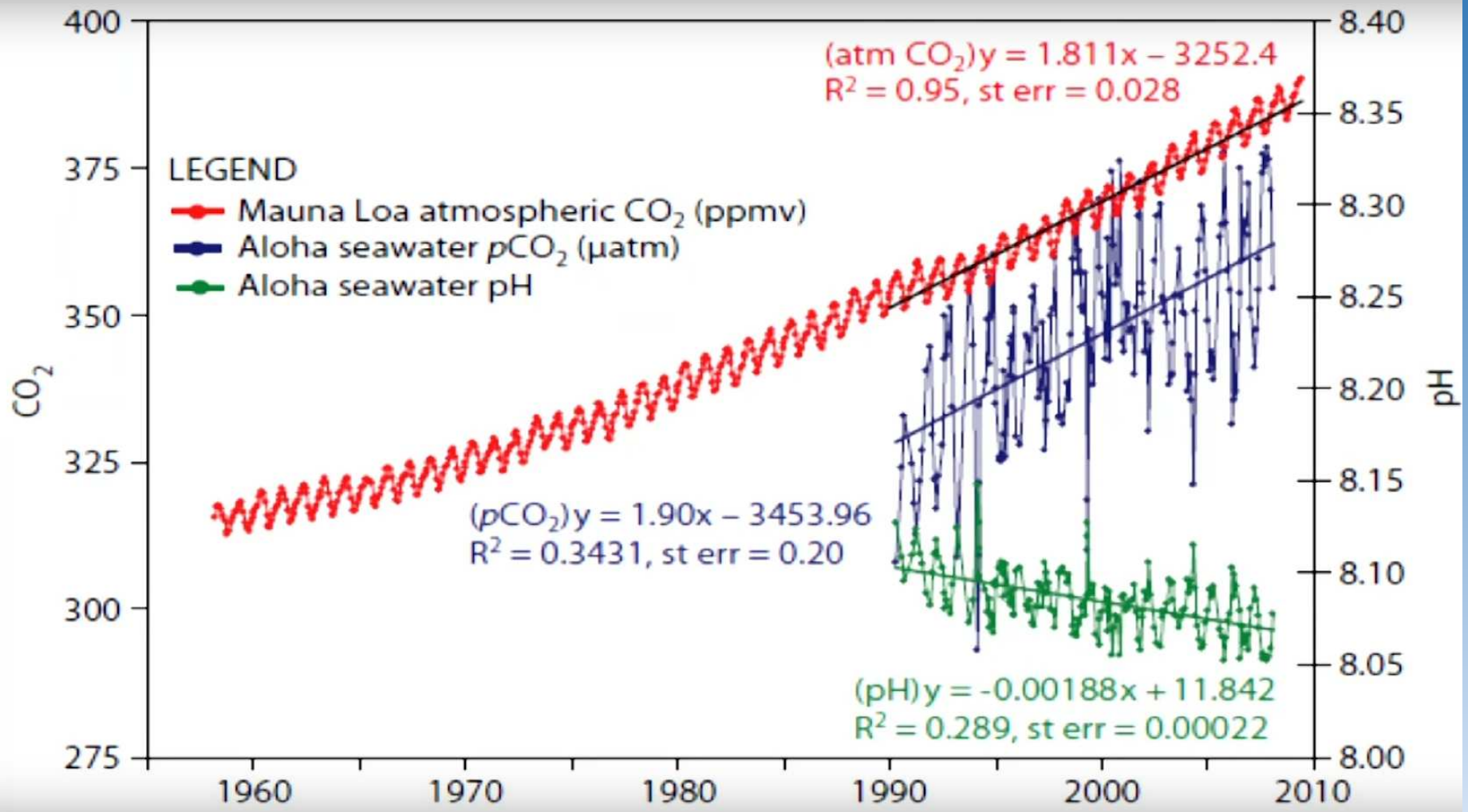
- 0.1 decrease in pH = 26% CO_3^{-2} ions

- reducing CO_3^{-2} makes it more difficult for organisms to make their shell – especially aragonitic ones





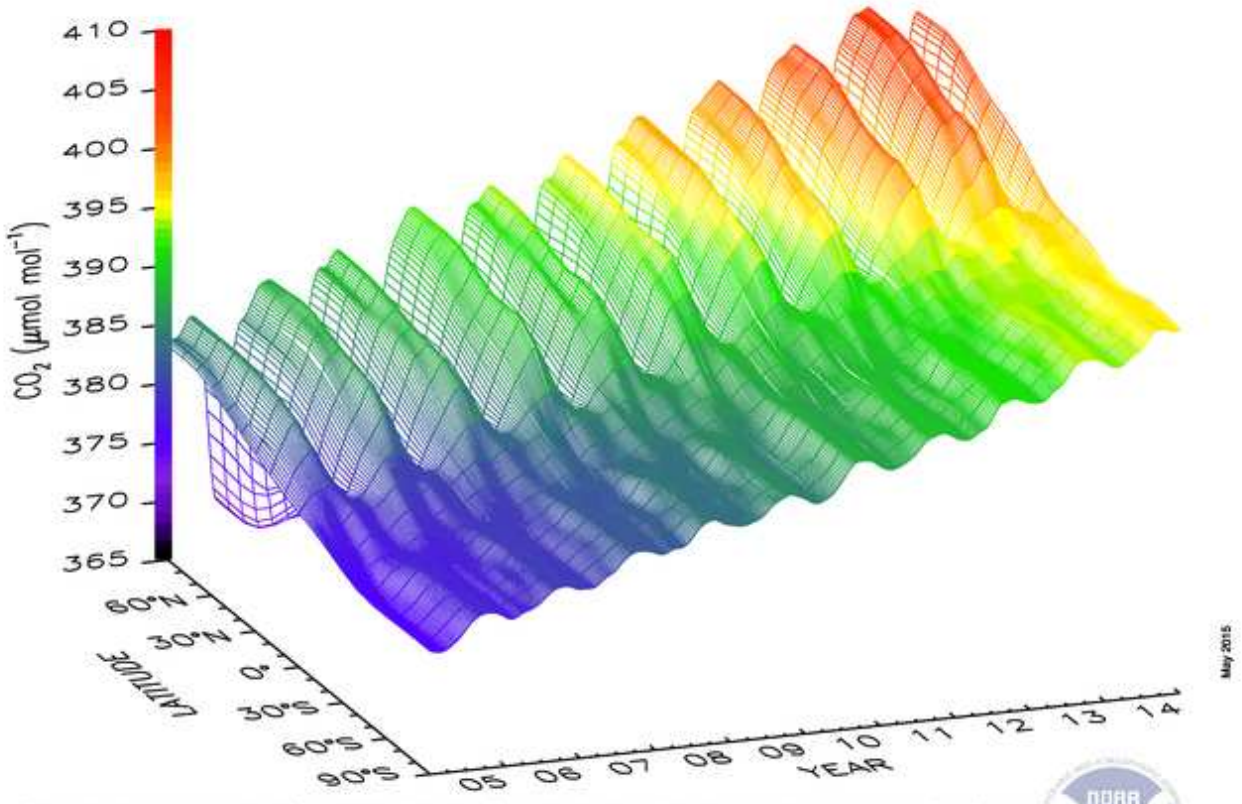
UQx DENIAL101x 5.3.3.1 Ocean acidification



http://www.skepticalscience.com/ocean-acidification-global-warming.htm

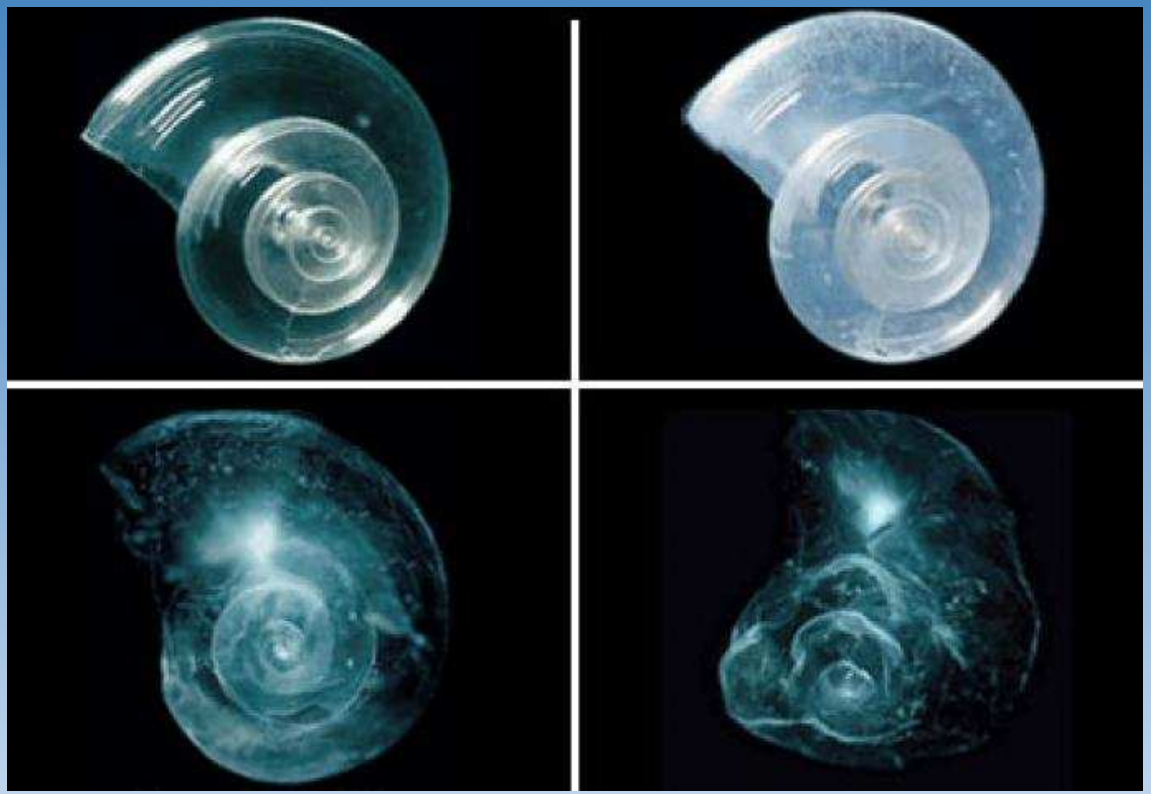
Global Distribution of Atmospheric Carbon Dioxide

NOAA ESRL Carbon Cycle



Three-dimensional representation of the latitudinal distribution of atmospheric carbon dioxide in the marine boundary layer. Data from the Carbon Cycle cooperative air sampling network were used. The surface represents data smoothed in time and latitude. Contact: Dr. Pieter Tans and Dr. Ed Dlugokencky, NOAA ESRL Carbon Cycle, Boulder, Colorado, (303) 497-6678, pieter.tans@noaa.gov, http://www.esrl.noaa.gov/gmd/ccgg/.

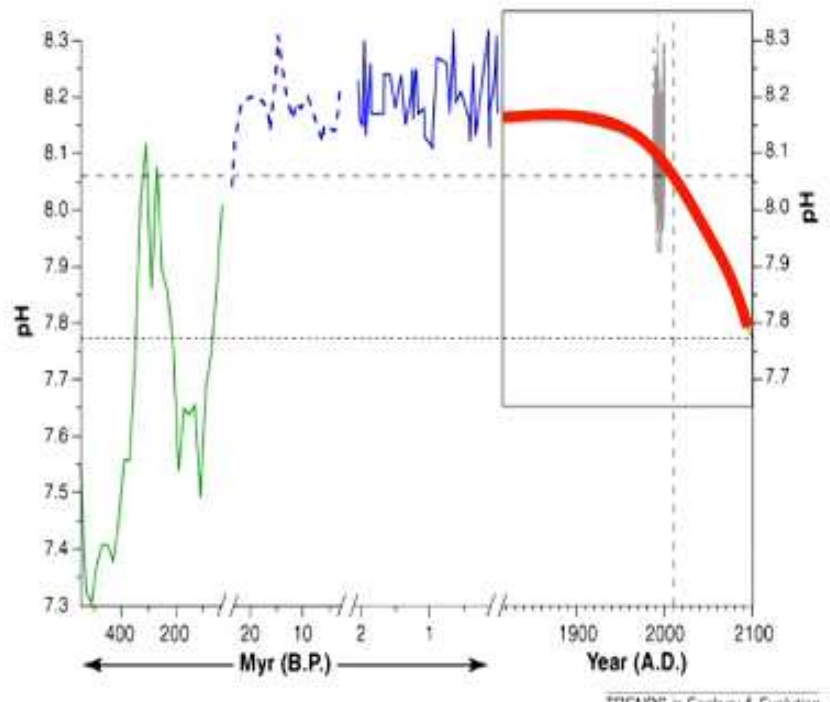
Pteropods



http://ocean.si.edu/ocean-acidification?gclid=Cj0KEQjw-b2wBRDcrKerwe-S5c4BEiQABprW-CHiUm54_8lcDb8ns9yN_W-5pYHfqqSf7QUb6MFohssaAmCM8P8HAQ

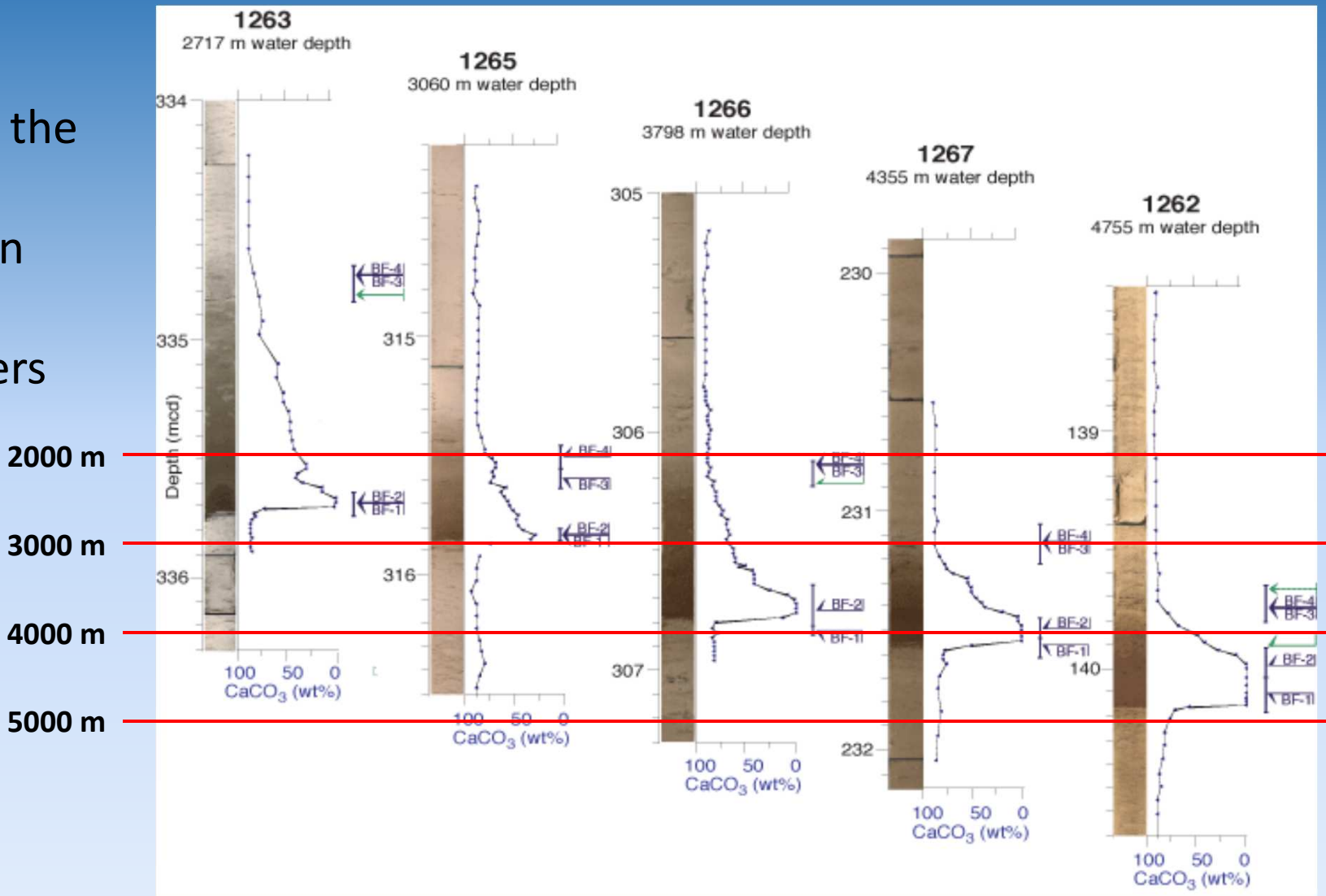
pH through time

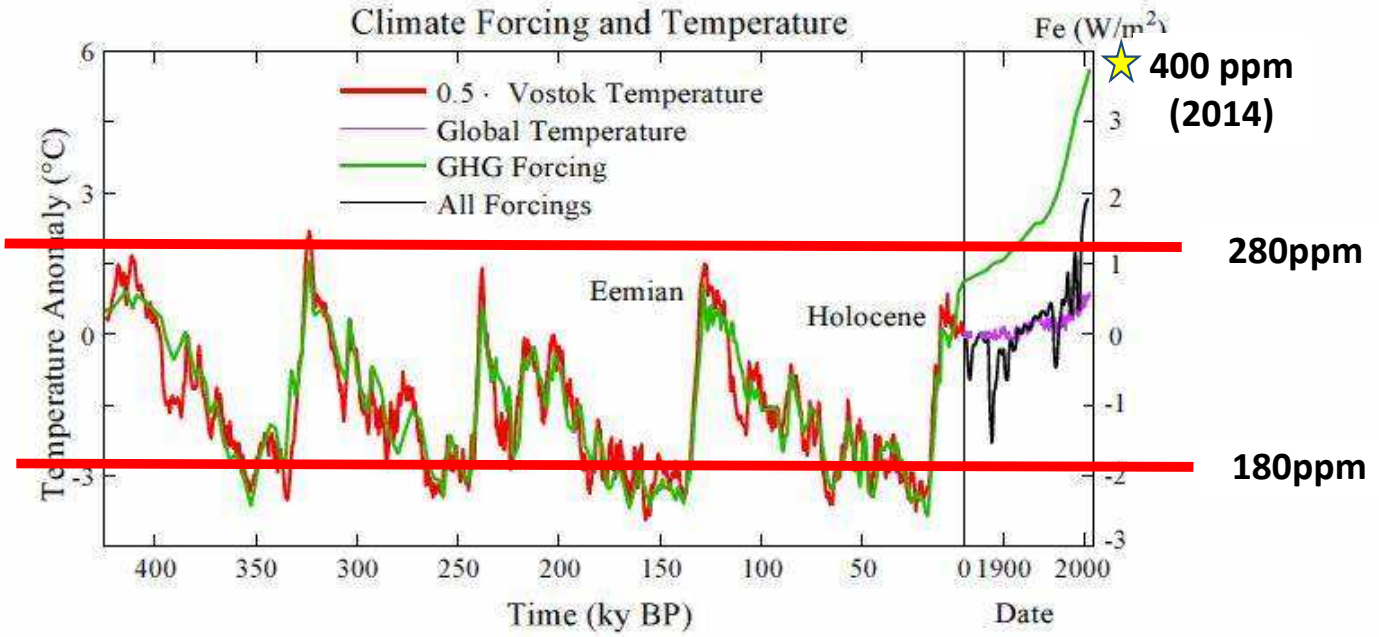
Here is a related lecture-video from Denial101x - Making Sense of Climate Science Denial

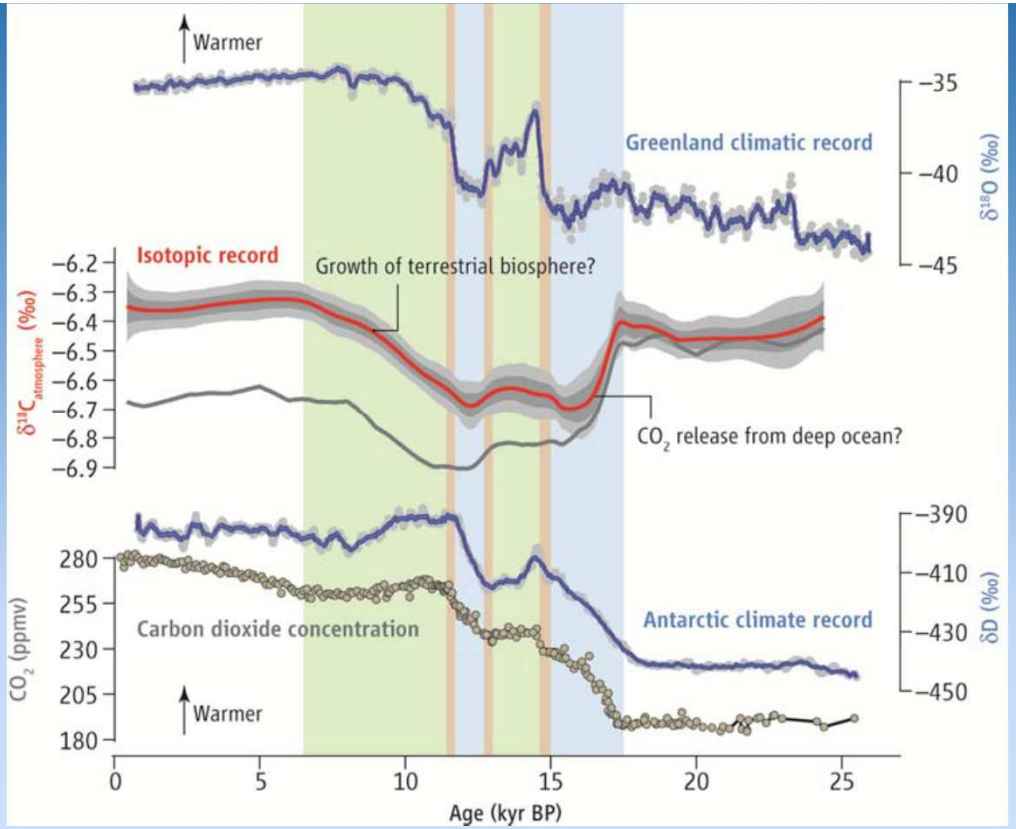


Attribution 5

PETM $CaCO_3$ shallowing of the Carbonate Compensation Depth (CCD)
~= 2000 meters




Climate Forcing and Temperature
Fe (W/m²)
0.5 · Vostok Temperature
Global Temperature
GHG Forcing
All Forcings
Eemian
Holocene
Temperature Anomaly (°C)
Time (ky BP)
Date
400 ppm
(2014)
280ppm
180ppm

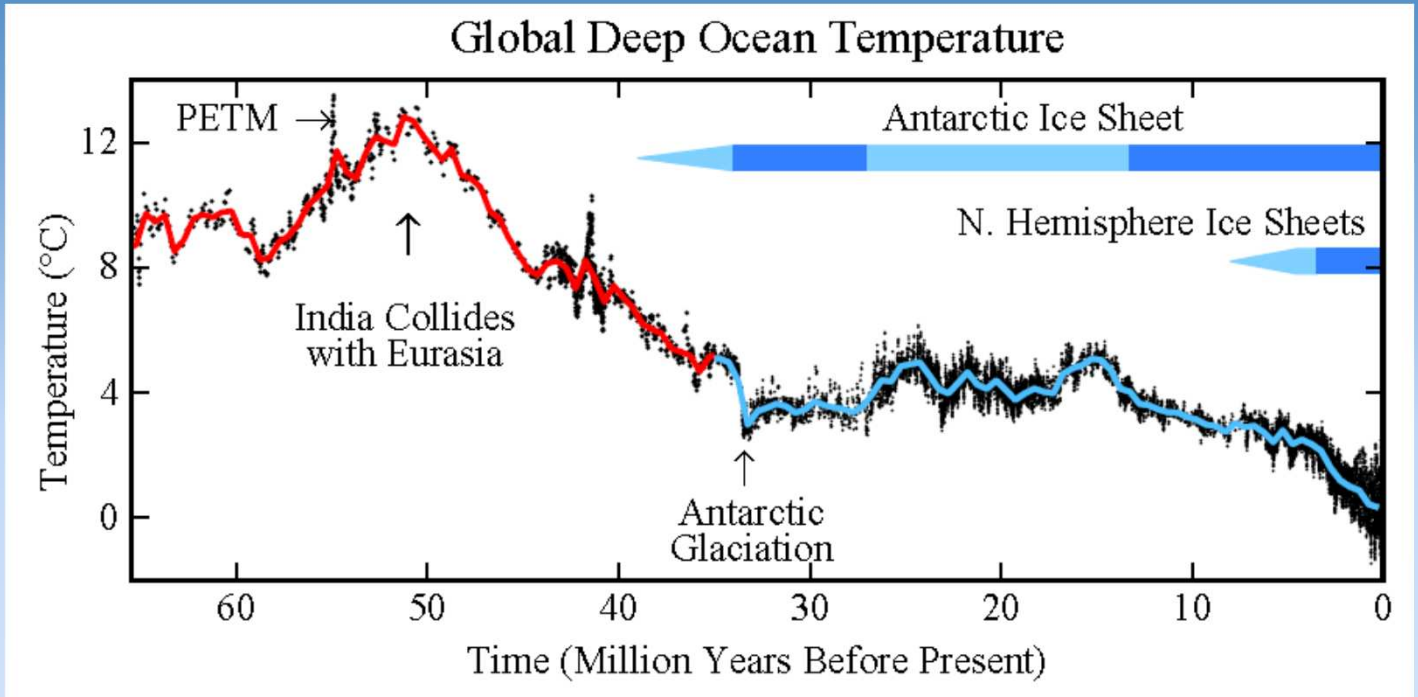


Glacial-interglacial change. Over the course of the past 24,000 years, CO_2 concentrations have risen (black curve) (*1*) as Earth emerged from glaciation, as shown by climate records from Greenland and Antarctica (blue curves) (*14*, *15*). Schmitt *et al*. (*2*) report a record of the change in the $^{13}C/^{12}C$ ratio of CO_2 during this time (red curve). The isotopic ratio is expressed in delta notation, where $\delta_{13}C$ is the deviation of a sample ratio from that of an internationally expected standard, expressed in parts per thousand. Comparison of the CO_2 record with the isotopic record provides insights into the mechanisms behind the CO_2 rise.

/ http://www.sciencemag.org/content/early/recent / 29 March 2012 / Page 1/ 10.1126/science.1219710

Rates of Change

What are the rates of change seen here?



50 million years ago (50 MYA) Earth was ice-free.

Atmospheric CO_2 amount was of the order of 1000 ppm 50 MYA.

Atmospheric CO_2 imbalance due to plate tectonics ~ 10^{-4} ppm per year.

Unprecedented rates of change

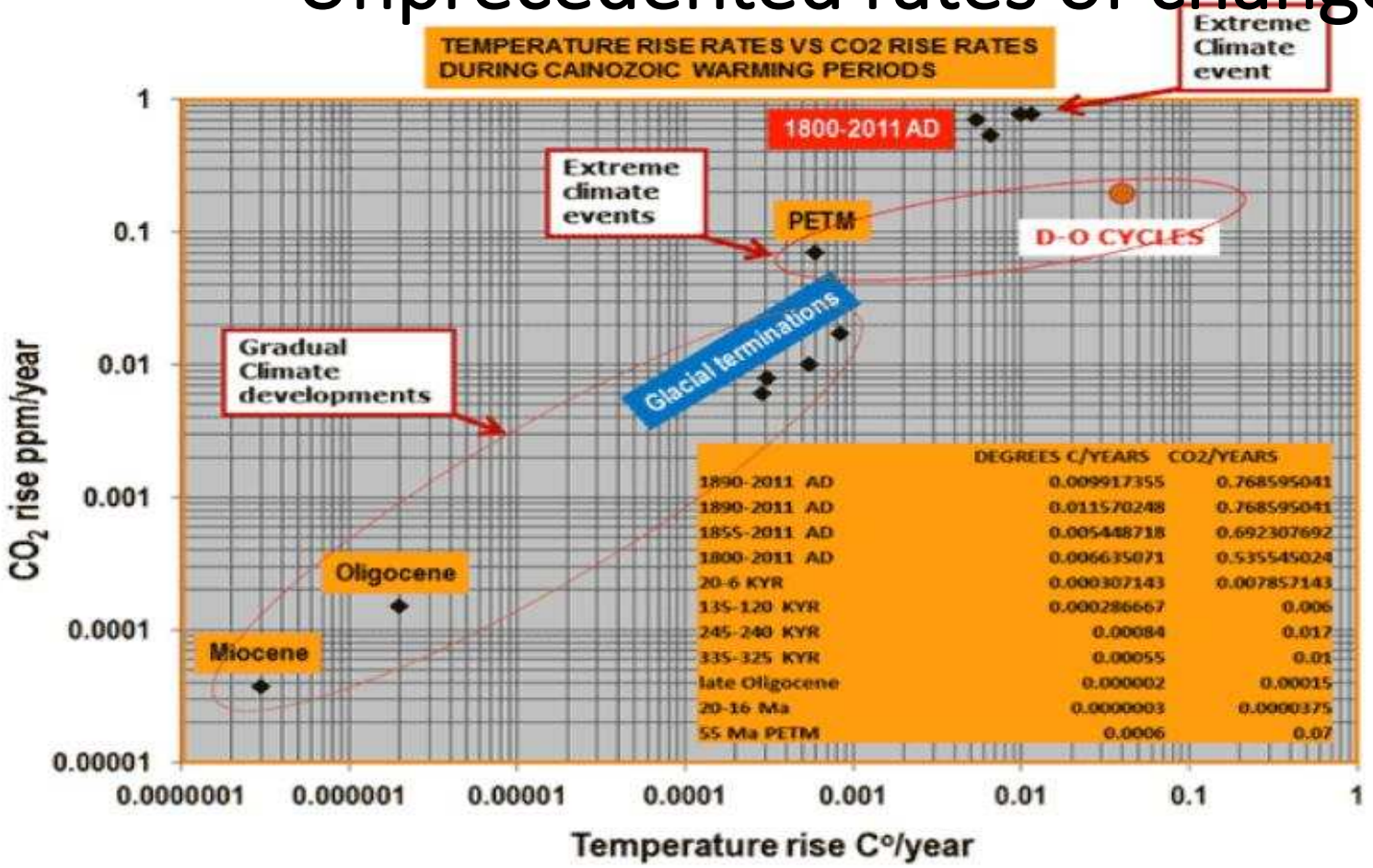


Figure 2: Relations between CO_2 rise rates and mean global temperature rise rates during warming periods, including the Paleocene-Eocene Thermal Maximum, Oligocene, Miocene, glacial terminations, Dansgaard-Oeschger cycles and the post-1750 period.

Past and present; future estimates

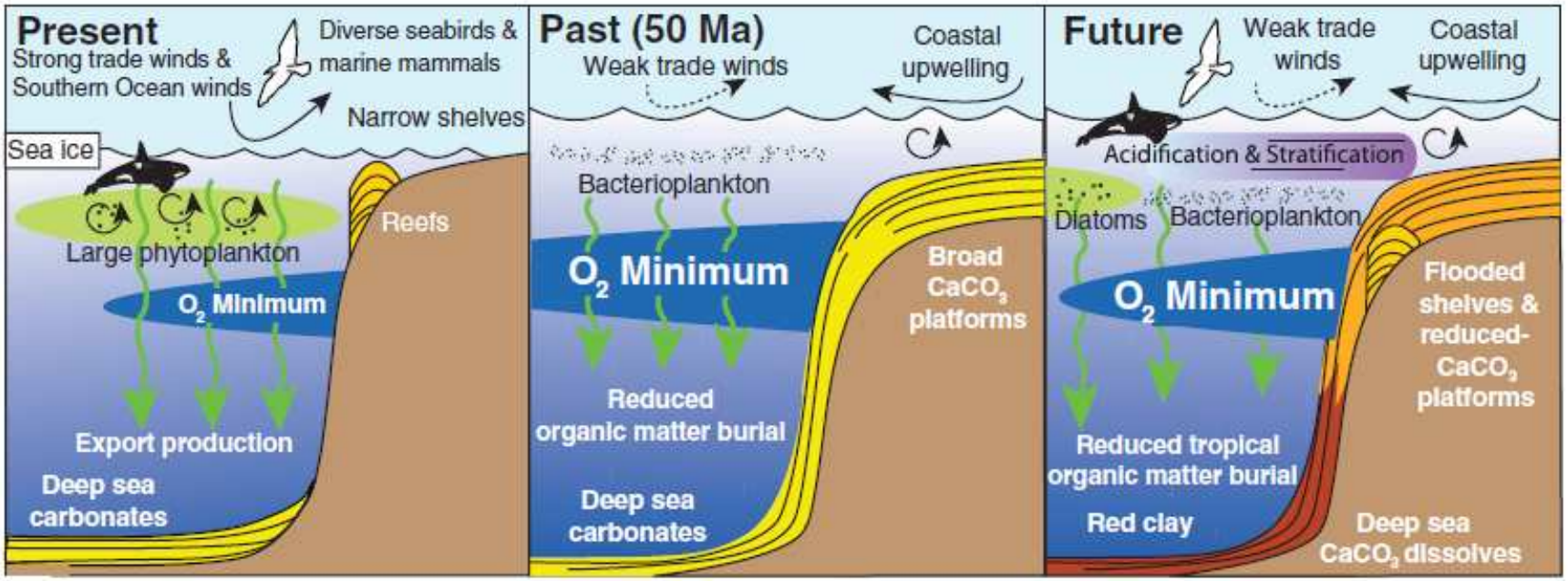
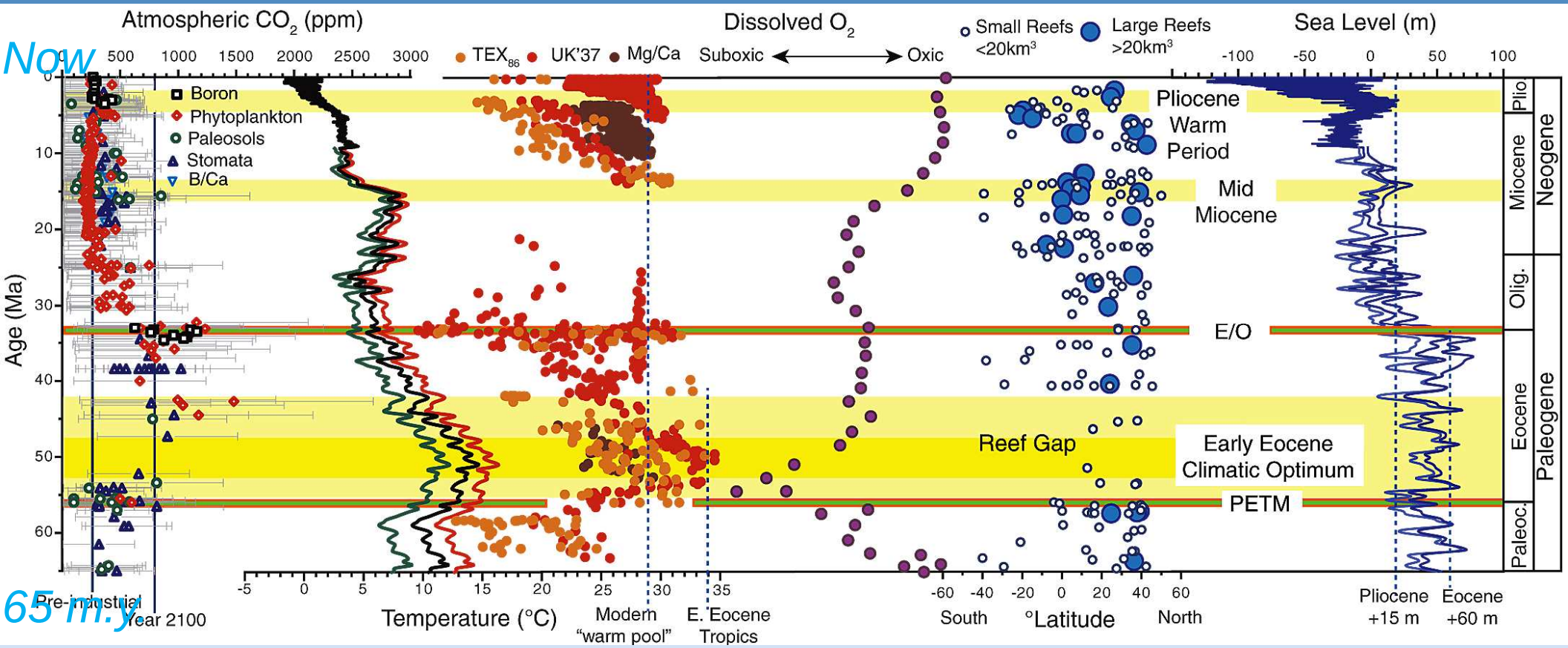


Fig. 1. Comparison of present, past, and future ocean ecosystem states. In the geologic past (middle panel), a warmer, less oxygenated ocean supported longer food chains based in phytoplankton smaller than present-day phytoplankton (left panel). The relatively low energy transfer between trophic levels in the past made it hard to support diverse and abundant top predators dominated by marine mammals and seabirds, and also reduced deep-sea organic matter burial. Equilibration of weathering with high atmospheric pCO_2 allowed carbonates to accumulate in parts of the deep sea. Reef construction was limited by high temperatures and coastal runoff even as high sea level created wide, shallow coastal oceans. In the future (right panel), warming will eventually reproduce many features of the past warm world but will also add transient impacts such as acidification and stratification of the surface ocean. Acidification will eventually be buffered by dissolving carbonates in the deep ocean, which create carbonate-poor "red clay." Stratification and the disappearance of multiyear sea ice will gradually eliminate parts of the polar ecosystems that have evolved in the past 34 million years and will restrict the abundance of short–food chain food webs that support marine vertebrates in the polar seas.

R. Norris et al., Science, 2013

History of oceans for last 65 m.y.

We know a great deal about past CO_2 , temp., etc.

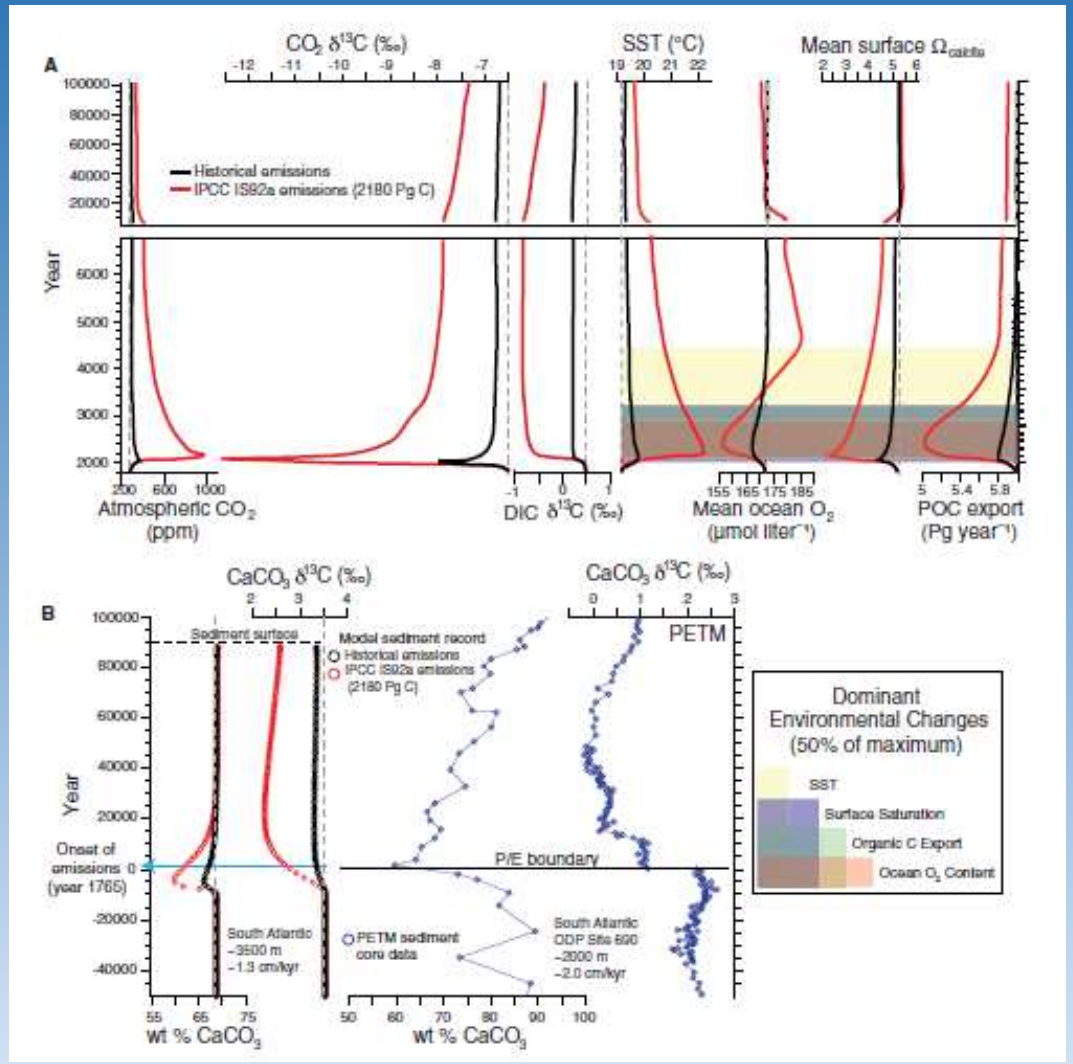


R. Norris et al., Science, 2013

History of oceans for last 65 m.y. and 100,000 year projections into the future

Using the past to model the future

…and a SEGWAY to Modeling



R. Norris et al., Science, 2013

Full list of Videos from Skeptical Science

http://www.skepticalscience.com/denial101x-videos-and-references.html