

Earth's Climate: Past, Present and Future

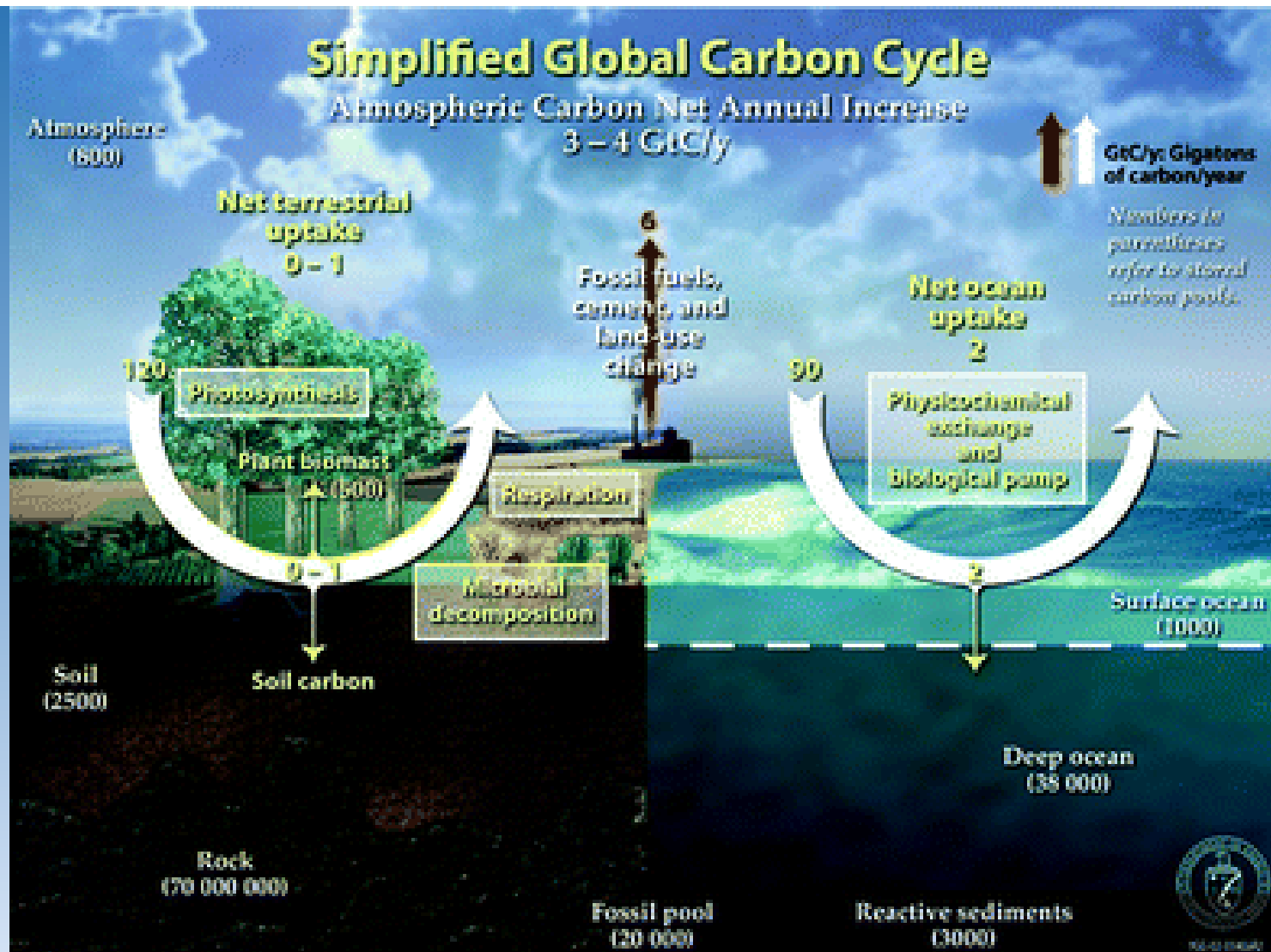
Fall Term - OLLI West: week 4, 10/6/2015
Paul Belanger

Ocean acidification, rates, modeling/future, IPCC

1. A little more on ocean acidification
2. Rates of change
3. Models
4. Future projections and feedbacks:
5. IPCC Fifth Assessment report (AR5): <http://www.ipcc.ch/report/ar5/>

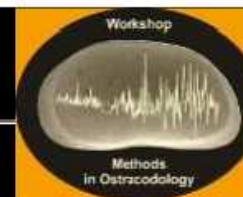
Ocean acidification

- Web page post Monday October , 2015 (and fb)
- Let's start with a video: <https://youtu.be/W1TZ8g8JYVU> from <http://www.skepticalscience.com/ocean-acidification-global-warming.htm>

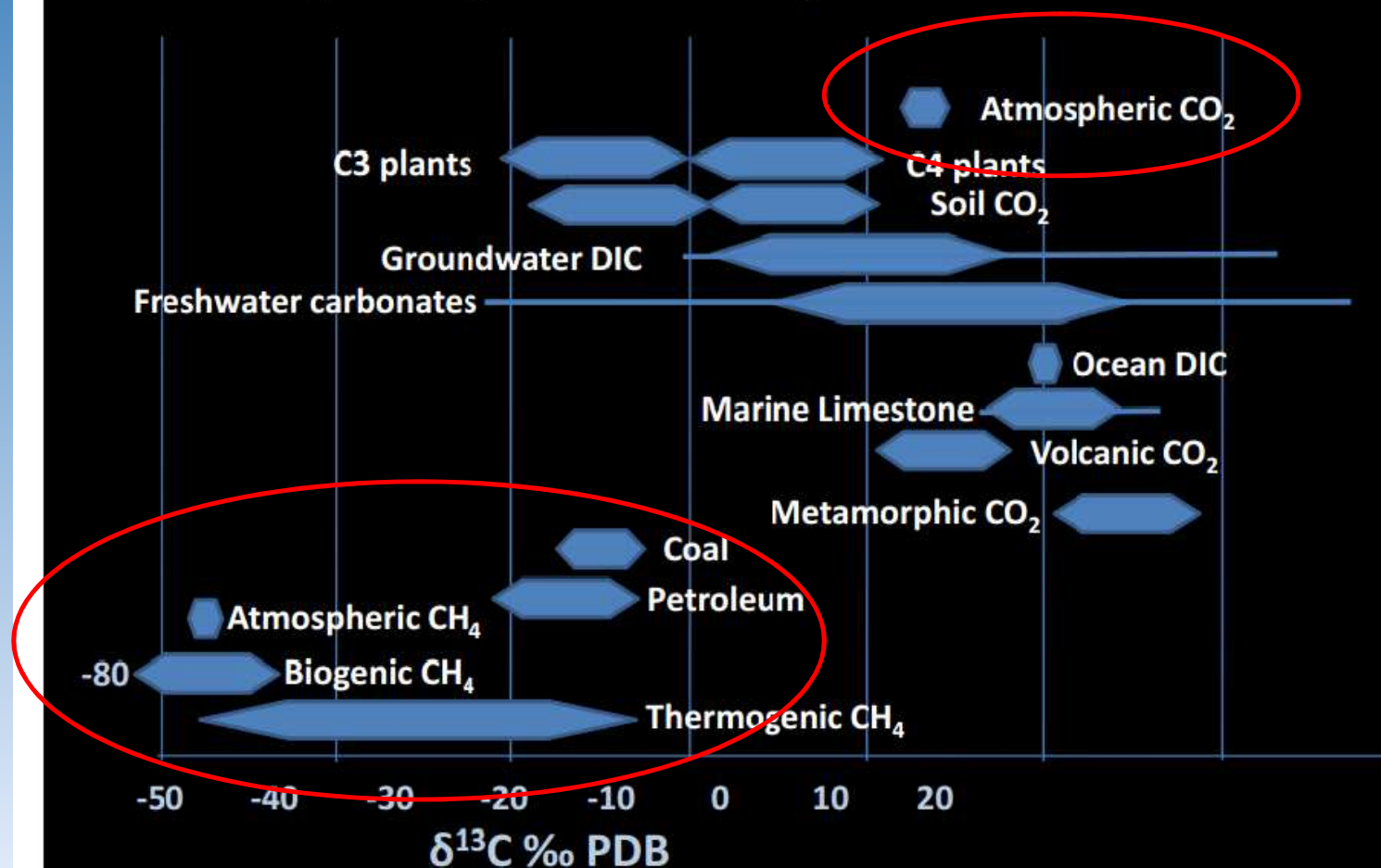


<http://www.pmel.noaa.gov/co2/story/Ocean+Carbon+Uptake>

Stable-Isotopes

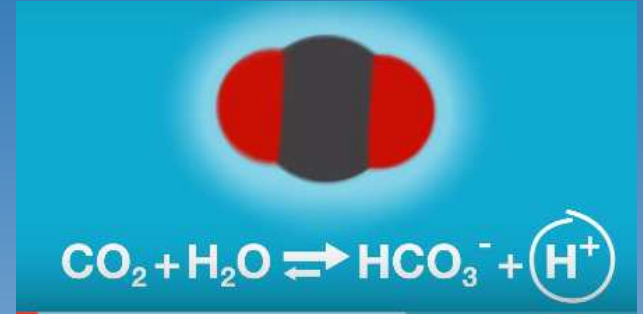


Graph showing $\delta^{13}\text{C}$ values for a range of different sources

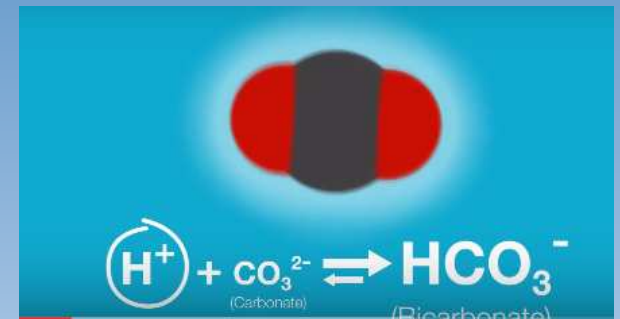


VIDEO HIGHLIGHTS: Ocean acidification

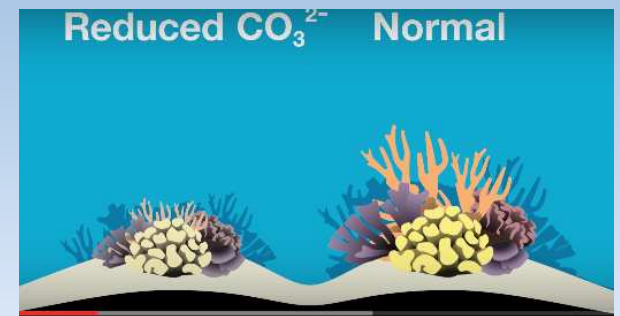
- Adding CO_2 adds H^+ ions making water more acidic (lowers pH)



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



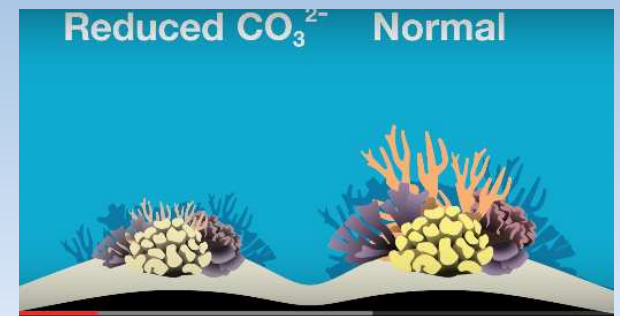
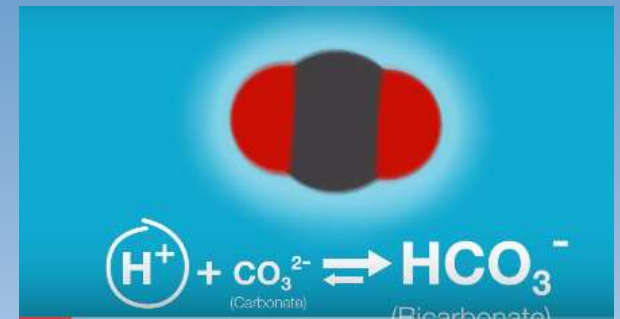
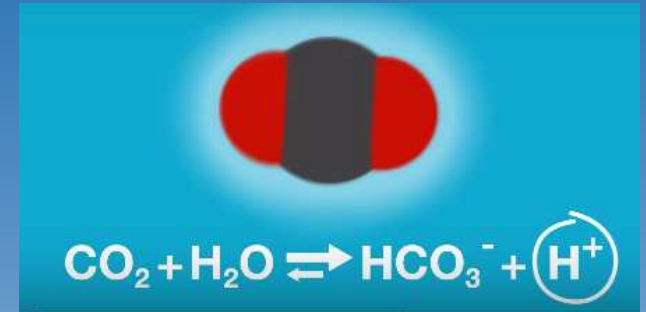
- reducing CO_3^{2-} makes it more difficult for organisms to make their shell – especially aragonitic ones

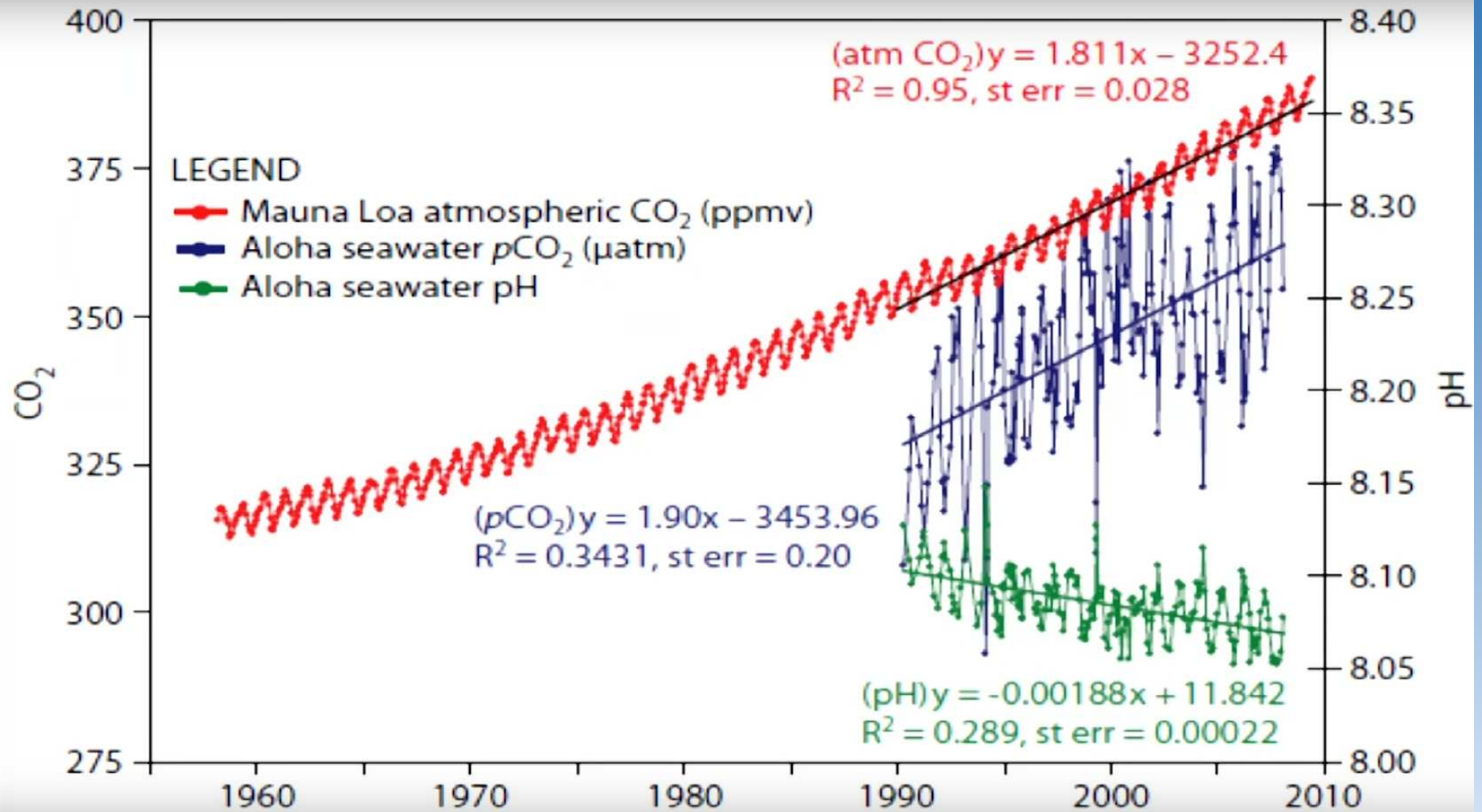


<http://www.skepticalscience.com/ocean-acidification-global-warming.htm>

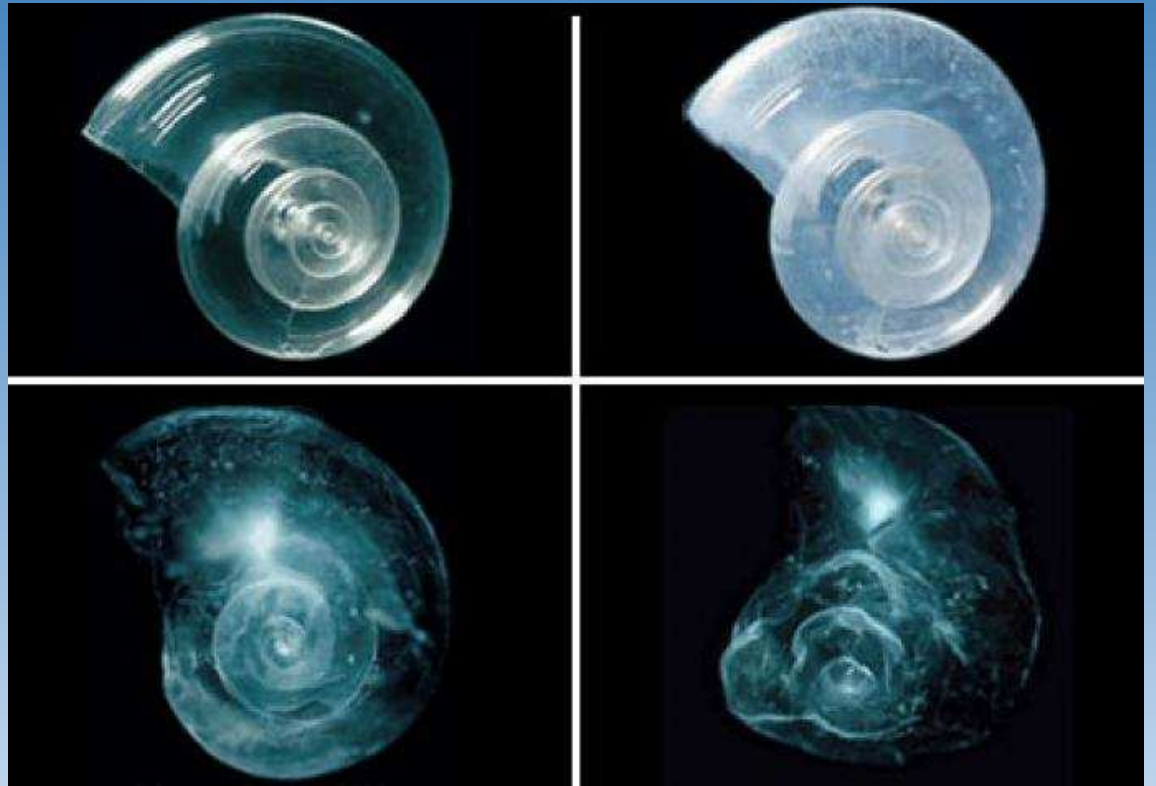
Continued

- 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





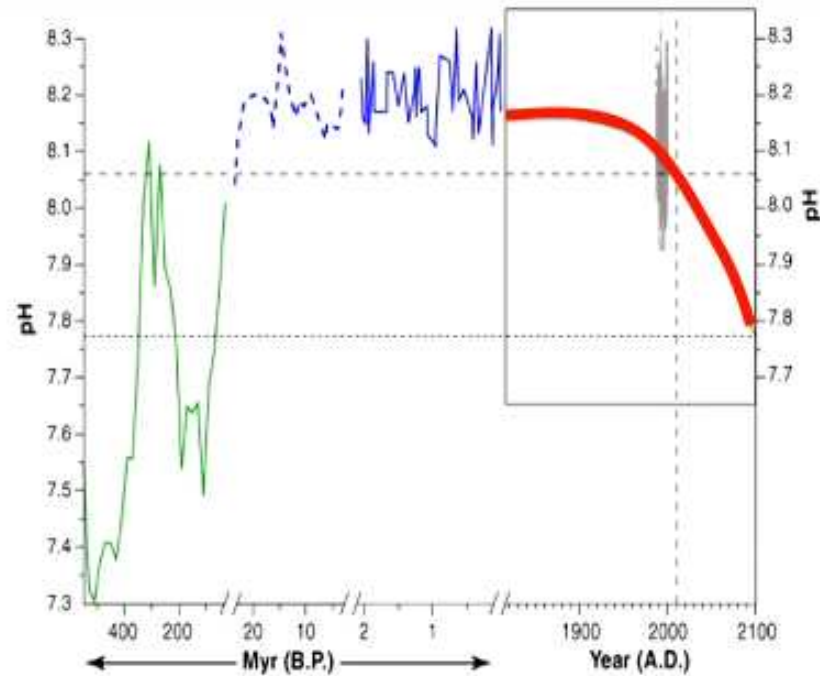
Pteropods



http://ocean.si.edu/ocean-acidification?gclid=Cj0KEQjw-b2wBRDcrKerwe-S5c4BEiQABprW-CHiUm54_8lcDb8ns9yN_W-5pYHfqgSf7QUb6MFohssaAmCM8P8HAQ

pH through time

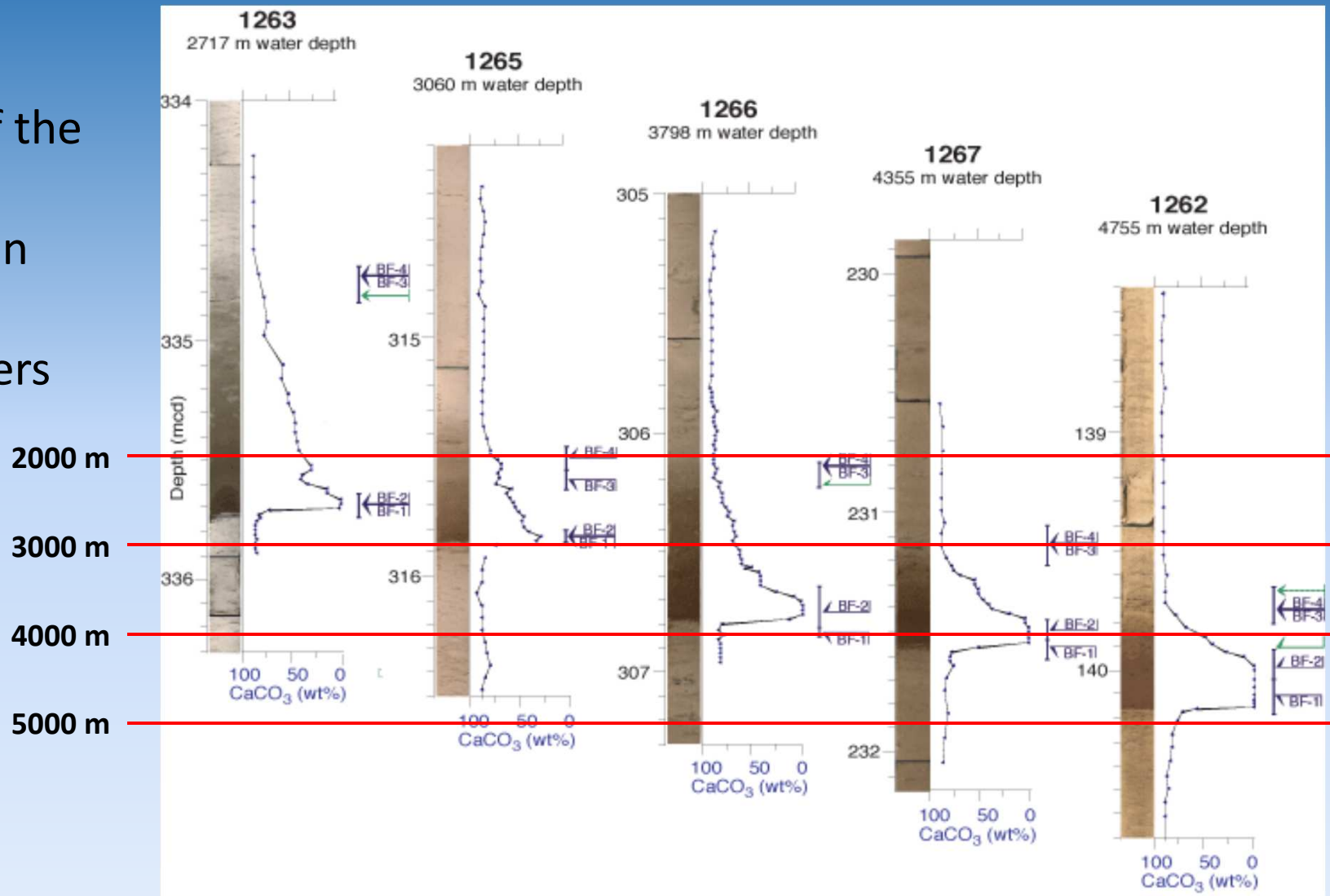
Here is a related lecture-video from [Denial101x - Making Sense of Climate Science Denial](#)

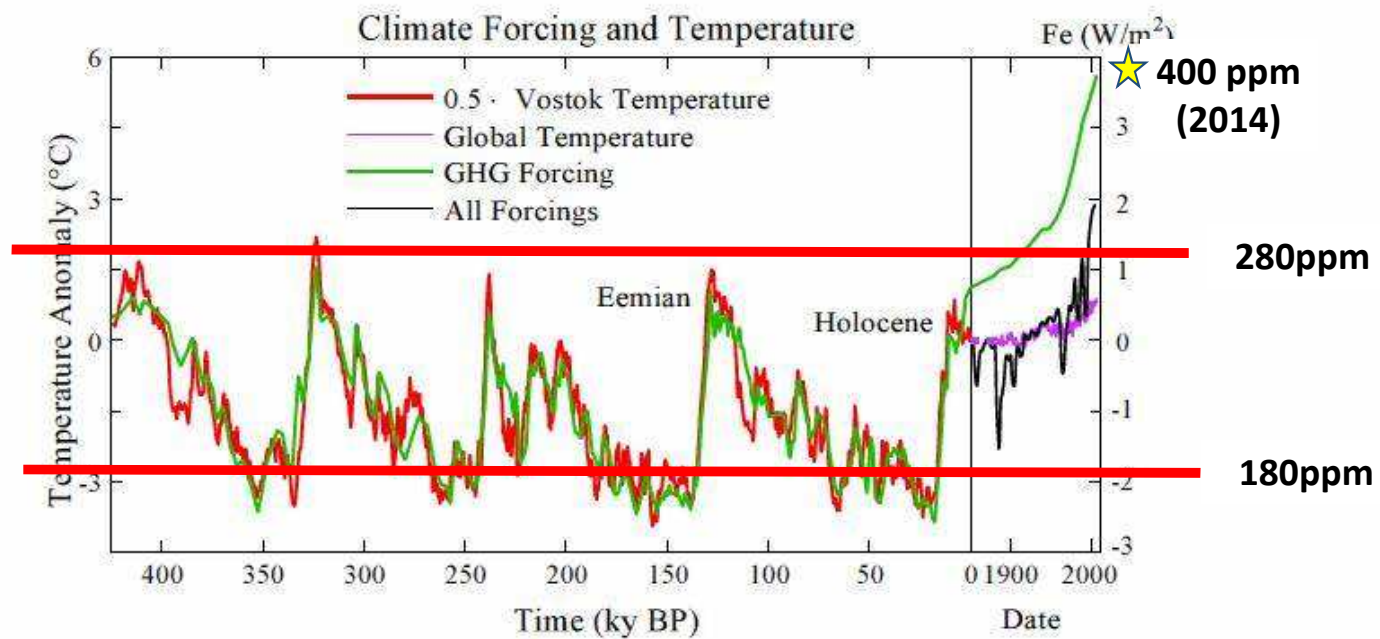


TRENDS in Ecology & Evolution

Attribution 5

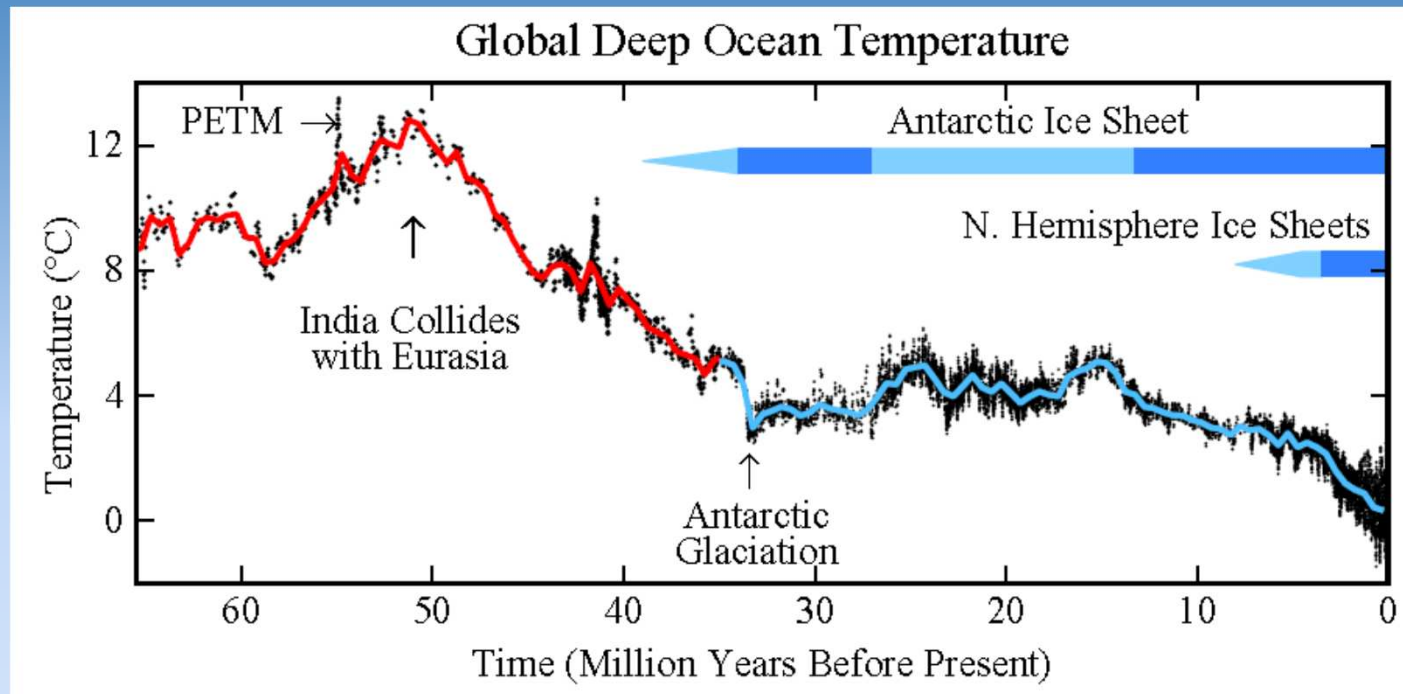
PETM CaCO_3
shallowing of the
Carbonate
Compensation
Depth (CCD)
≈ 2000 meters





Rates of Change

What are the rates of change seen here?



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

Atmospheric CO₂ amount was of the order of 1000 ppm 50 MYA.

Atmospheric CO₂ imbalance due to plate tectonics $\sim 10^{-4}$ ppm per year.

Unprecedented rates of change

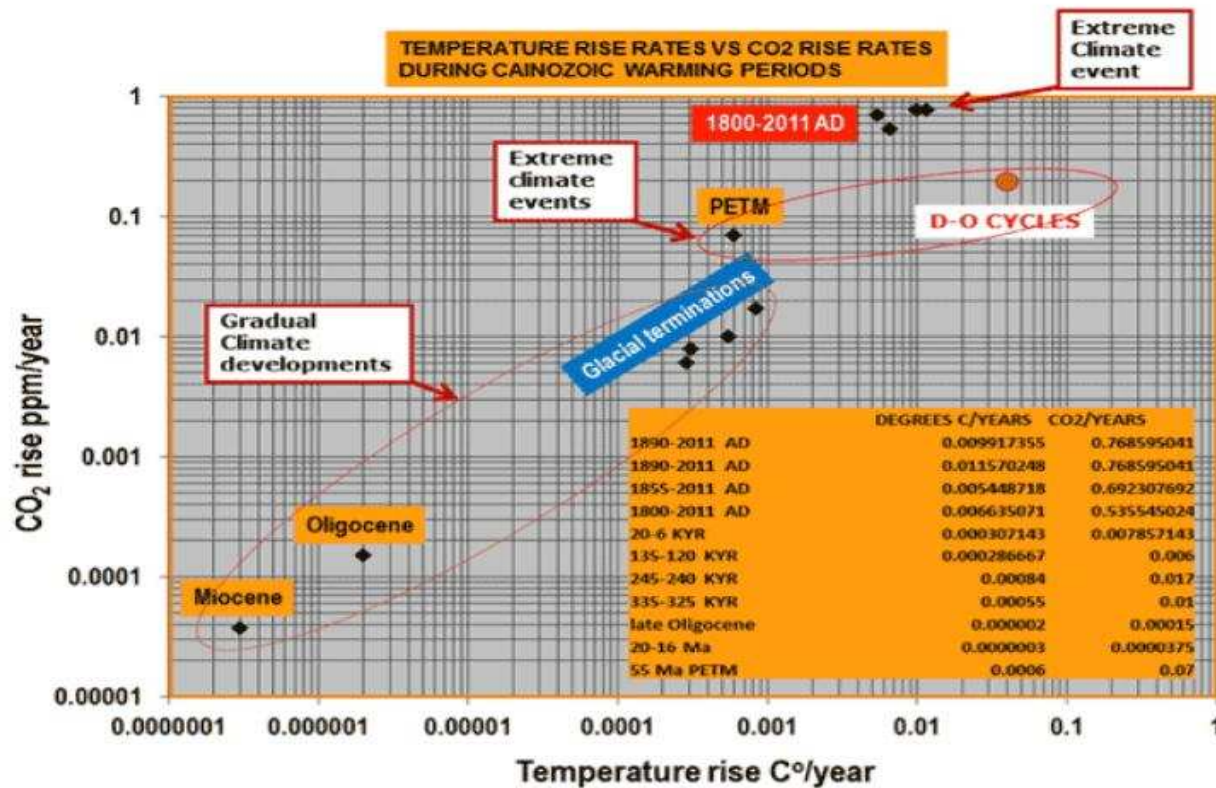


Figure 2: Relations between CO₂ rise rates and mean global temperature rise rates during warming periods, including the Paleocene-Eocene Thermal Maximum, Oligocene, Miocene, glacial terminations, Dansgaard-Oeschger cycles and the post-1750 period.

Past and present; future estimates

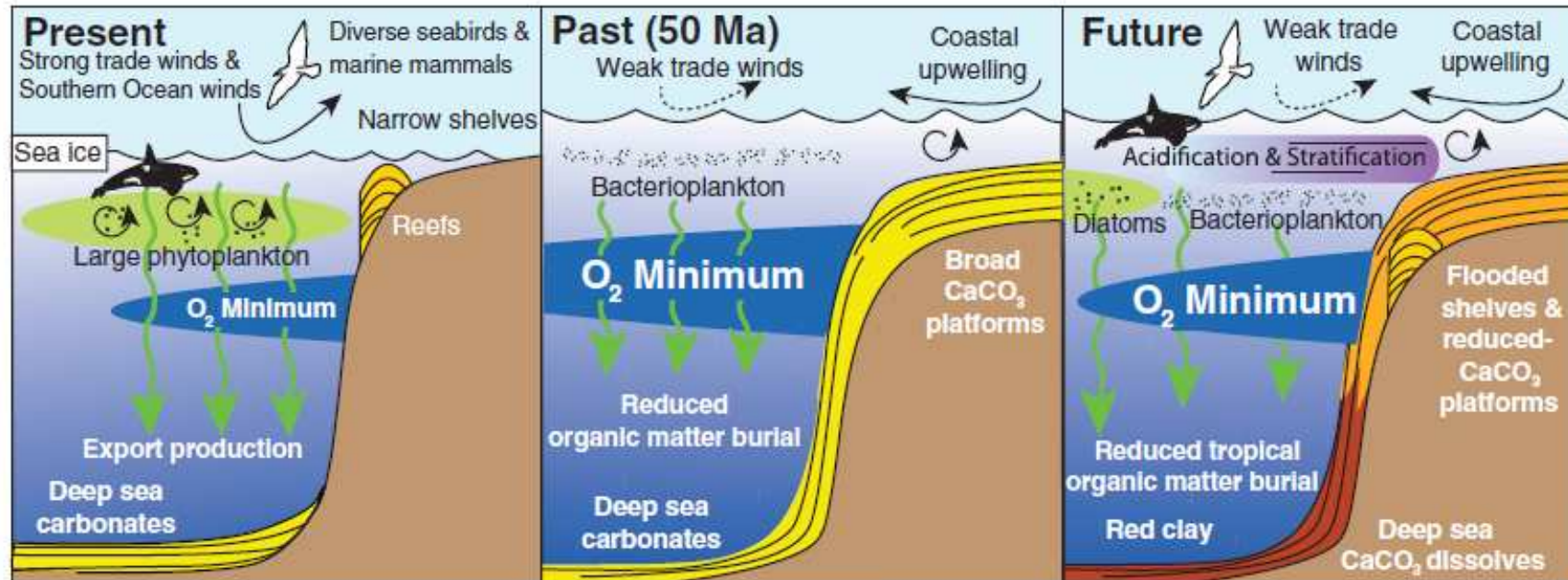


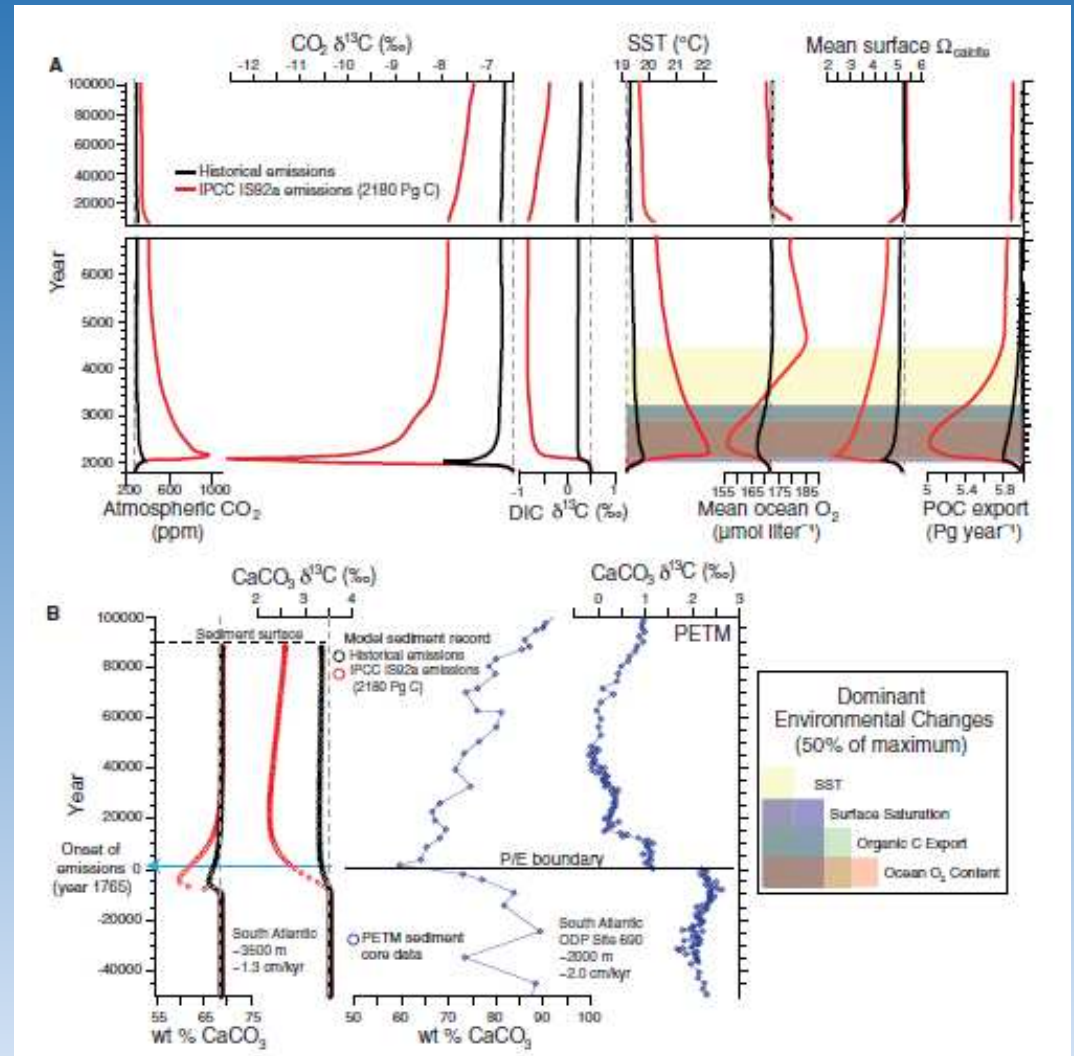
Fig. 1. Comparison of present, past, and future ocean ecosystem states. In the geologic past (middle panel), a warmer, less oxygenated ocean supported longer food chains based in phytoplankton smaller than present-day phytoplankton (left panel). The relatively low energy transfer between trophic levels 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 $p\text{CO}_2$ 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.

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



But first – terminology you'll see being used regarding misrepresentation

5 CHARACTERISTICS OF SCIENCE DENIAL



Models – 2 videos

Principles that models are built on – view today

<https://www.youtube.com/watch?v=mYU2uawYPIE&feature=youtu.be>

From the experts: Climate models – leaving it for you to view at your leisure:

<https://www.youtube.com/watch?v=PZo1TYpsy2U&feature=youtu.be>

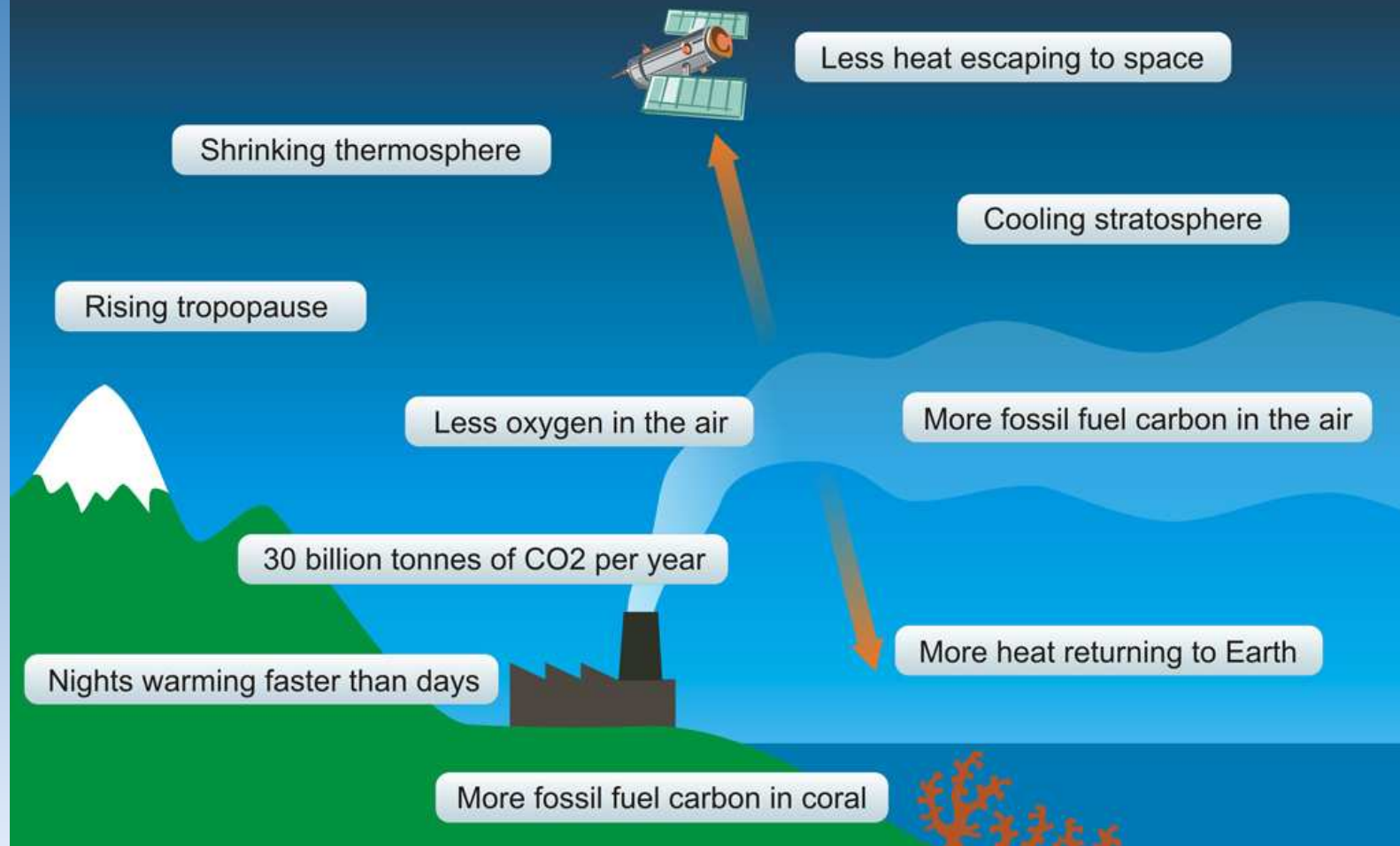
NOAA's Science On a Sphere (SOS)

[http://sos.noaa.gov/What is SOS/index.html](http://sos.noaa.gov/What_is_SOS/index.html) ; used at DMNS where I've been co-developing a climate change playlist, soon to be released. In the meantime see <http://spaceodyssey.dmns.org/exhibitsprograms/interactives-exhibits/sos.aspx>

Full list of Videos from Skeptical Science

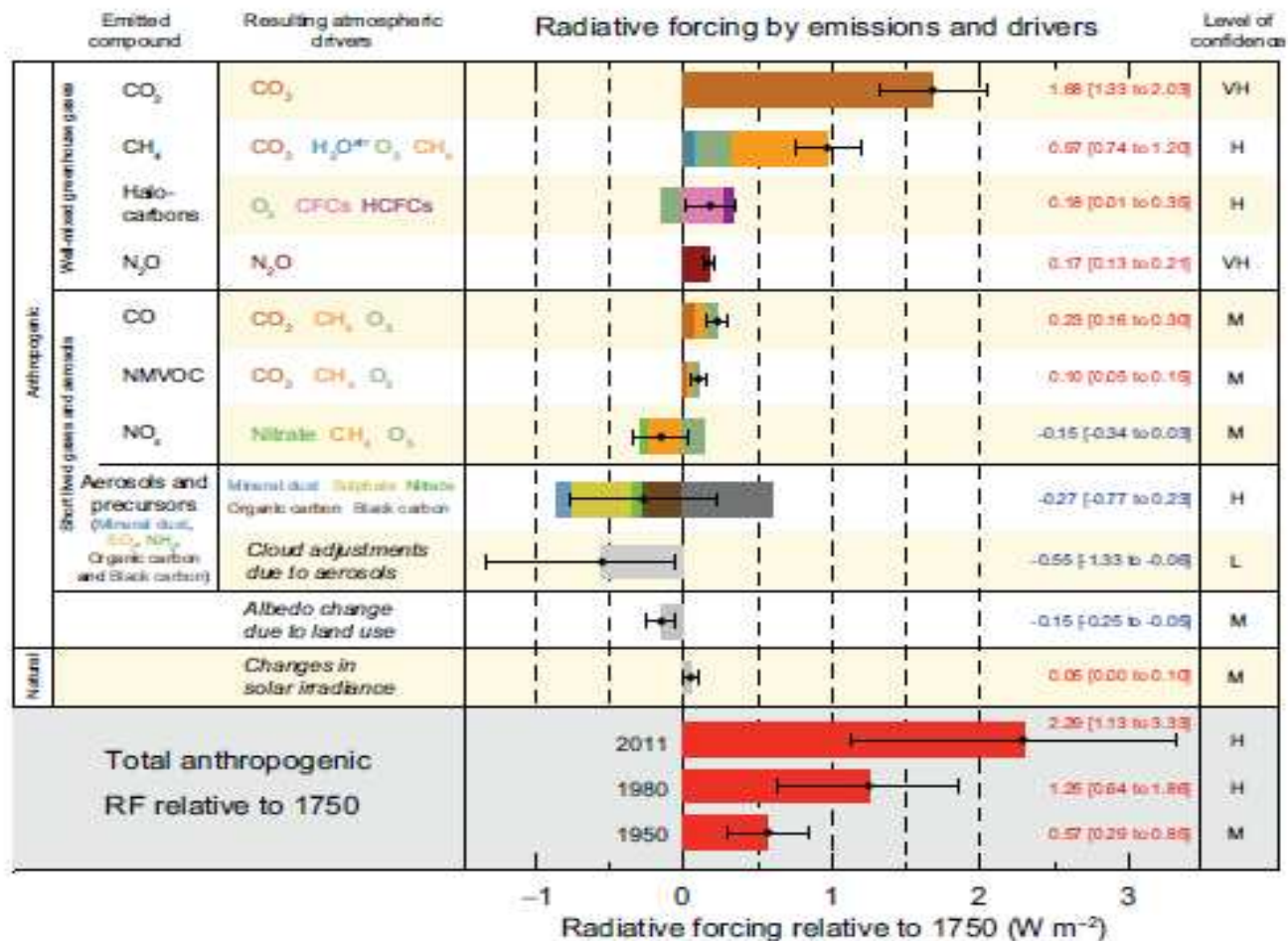
<http://www.skepticalscience.com/denial101x-videos-and-references.html>

10 Indicators of a Human Fingerprint on Climate Change



1: THE CLIMATE IS WARMING

- Drivers, aka forcings (causes)



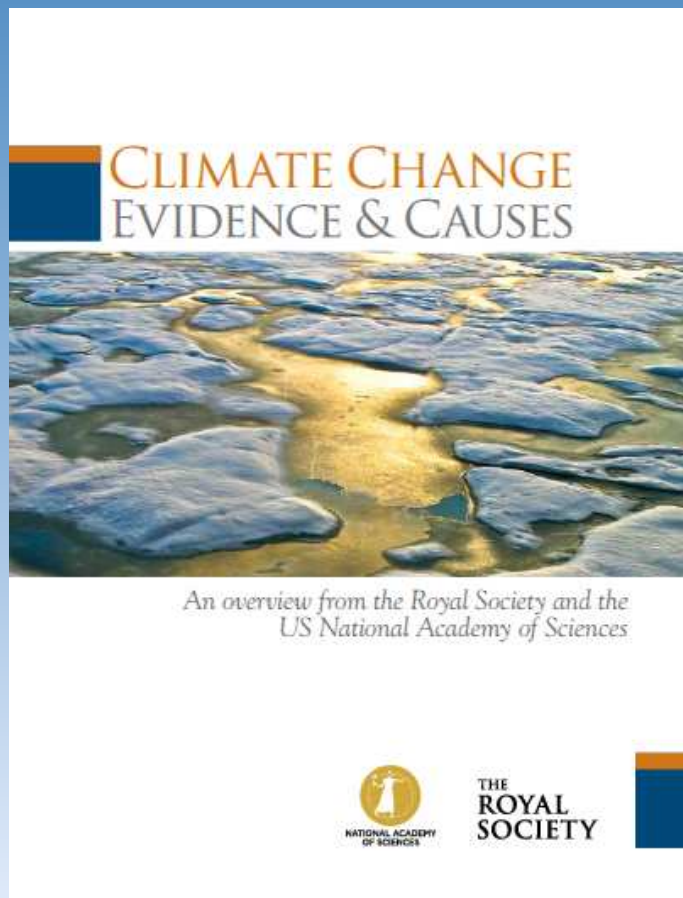
Intergovernmental Panel on Climate Change IPCC

- <http://www.ipcc.ch/report/ar5/> - three working groups:
 1. WG I: Physical Science Basis – what we've been dealing with thusfar
 - Especially headlines for policy makers and chapters 5 (paleoclimate), 6 (Carbon) and 9 (models) that can be found at http://denverclimatestudygroup.com/?page_id=63
 2. WG II: Impacts, Adaptations and Vulnerability; Part A: Global and Sectoral Aspects
 3. WG III: Mitigation of Climate change – in coming weeks
- Synthesis report – my other PowerPoint based on <http://www.ipcc.ch/report/ar5/syr/>

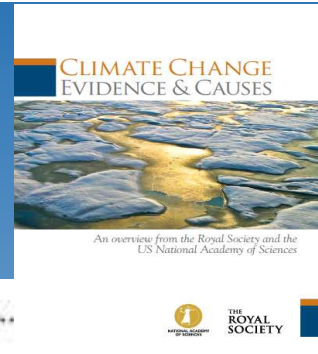
Joint U.S. National Academy of Science and Royal Society 20-point summary:

- OR: Joint U.S. National Academy of Science and Royal Society 20-point summary: [20-point Climate-Change Summary](#) (pdf) – summarized in the following 3 slides

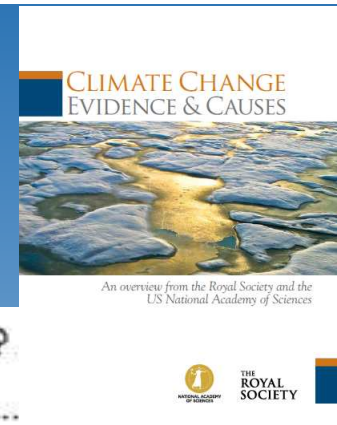
Joint U.S. National Academy of Science and Royal Society 20-point summary:



20
Q/As
to follow this
slide



- 1 Is the climate warming?
- 2 How do scientists know that recent climate change is largely caused by human activities?
- 3 CO₂ is already in the atmosphere naturally, so why are emissions from human activity significant?
- 4 What role has the Sun played in climate change in recent decades?
- 5 What do changes in the vertical structure of atmospheric temperature—from the surface up to the stratosphere—tell us about the causes of recent climate change?
- 6 Climate is always changing. Why is climate change of concern now?
- 7 Is the current level of atmospheric CO₂ concentration unprecedented in Earth's history?
- 8 Is there a point at which adding more CO₂ will not cause further warming? 1
- 9 Does the rate of warming vary from one decade to another?
- 10 Does the recent slowdown of warming mean that climate change is no longer happening?



- 11 If the world is warming, why are some winters and summers still very cold?
- 12 Why is Arctic sea ice decreasing while Antarctic sea ice is not?
- 13 How does climate change affect the strength and frequency of floods, droughts, hurricanes, and tornadoes?
- 14 How fast is sea level rising?
- 15 What is ocean acidification and why does it matter?
- 16 How confident are scientists that Earth will warm further over the coming century?
- 17 Are climate changes of a few degrees a cause for concern?
- 18 What are scientists doing to address key uncertainties in our understanding of the climate system?
- 19 Are disaster scenarios about tipping points like 'turning off the Gulf Stream' and release of methane from the Arctic a cause for concern?
- 20 If emissions of greenhouse gases were stopped, would the climate return to the conditions of 200 years ago?

Joint U.S. National Academy of Science and Royal Society 20-point summary:

- FOR ANSWERS SEE MY OTHER PowerPoint

Joint U.S. National Academy of Science and Royal Society 20-point summary:

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- If we are so concerned about leaving a national debt to our children and grandchildren, and BTW we should be, shouldn't we put the costs of climate change as part of that equation?
- For those that don't accept climate change maybe it would be a good thing to limit CO₂ into the atmosphere anyway, especially at the rates we are putting it into the atmosphere – BECAUSE OF OCEAN ACIDIFICATION issues and the law of unintended consequences!

A Climate knowledge quiz:

- <http://www.csmonitor.com/Environment/2014/0827/Climate-change-Is-your-opinion-informed-by-science-Take-our-quiz/Gas>

Climate change: Is your opinion informed by science? Take our quiz!

Quiz results

Your score	Average reader score
	52%