



This is the print version of the [Skeptical Science](http://sks.to/acid) article '[Ocean acidification isn't serious](http://sks.to/acid)', which can be found at <http://sks.to/acid>.

Ocean acidification: global warming's evil twin

What The Science Says:

The current debate on the connection between CO₂ emissions and climate change has largely overlooked an independent and equally serious problem, the increasing acidity of our oceans. Last December, the respected journal "Oceanography" published projections (see graphic below) for this rising acidity, measured by falling pH [i], through to the end of the century [ii].

Climate Myth: Ocean acidification isn't serious

'Our harmless emissions of trifling quantities of carbon dioxide cannot possibly acidify the oceans. Paper after paper after learned paper in the peer-reviewed literature makes that quite plain. Idso cites some 150 scientific sources, nearly all of them providing hard evidence, by measurement and experiment, that there is no basis for imagining that we can acidify the oceans to any extent large enough to be measured even by the most sensitive instruments.' ([Christopher Monckton](#))

The current debate on the connection between CO₂ emissions and climate change has largely overlooked an independent and equally serious problem, the increasing acidity of our oceans. Last December, the respected journal "Oceanography" published projections (see graphic below) for this rising acidity, measured by falling pH [i], through to the end of the century [ii]. In 2095, the projected average ocean surface pH is 7.8, and lower still in the Arctic Ocean.

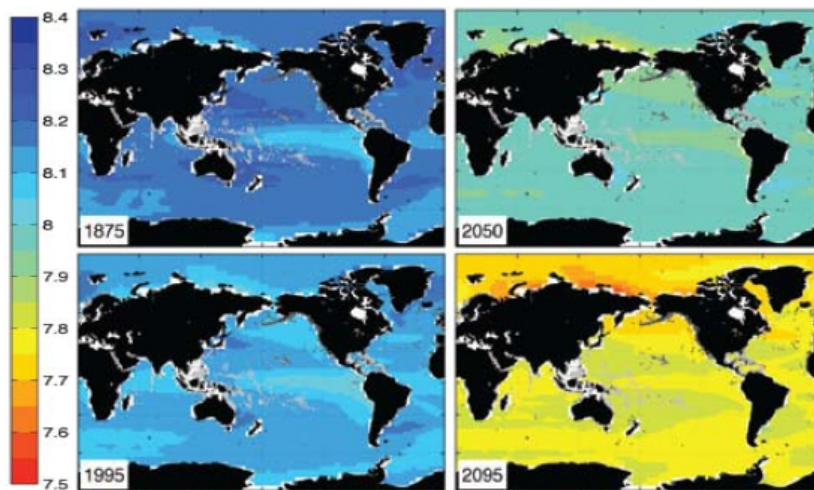


Fig 1: Ocean surface pH - historical values and projected future values based on current emission projections.

Source: US National Center for Atmospheric Research Community Climate System Model 3.1 (CC SM3)-modeled decadal mean pH at the sea surface centered around the years 1875, 1995, 2050, and 2095.

CO₂ in the atmosphere has increased from 278 ppm in pre-industrial times to 390 ppm today. During this time, the amount of CO₂ dissolved in the ocean has risen by more than 30% [iii], decreasing the pH of the ocean by 0.11 units. As with CO₂ and global warming, there is some lag between cause and effect. That means that, even if all carbon emissions stopped today, we are committed to a further drop of up to 0.1 units.

The close relationship between CO₂ in the atmosphere, CO₂ dissolved in the ocean, and the effect of the latter in falling pH, is illustrated by the graph [iv] below:

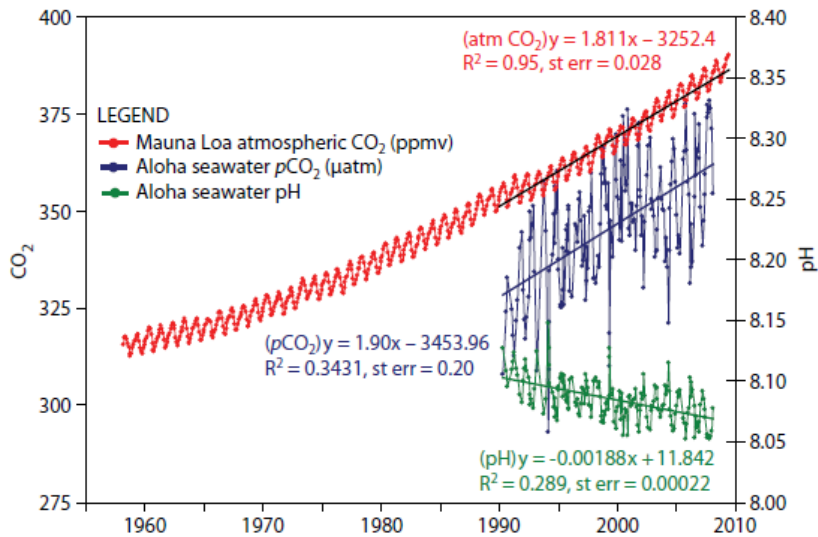
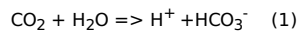
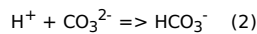


Fig 2: Annual variations in atmospheric CO₂, oceanic CO₂, and ocean surface pH. Strong trend lines for rising CO₂ and falling pH.

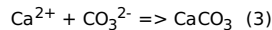
CO₂ dissolves in water to form carbonic acid. (It is worth noting that carbonic acid is what eats out limestone caves from our mountains.) In the oceans, carbonic acid releases hydrogen ions (H⁺), reducing pH, and bicarbonate ions (HCO₃⁻).



The additional hydrogen ions released by carbonic acid bind to carbonate ions (CO₃²⁻), forming additional HCO₃⁻.



This reduces the concentration of CO₃²⁻, making it harder for marine creatures to take up CO₃²⁻ to form the calcium carbonate needed to build their exoskeletons.



The two main forms of calcium carbonate used by marine creatures are calcite and aragonite. Decreasing the amount of carbonate ions in the water makes conditions more difficult for both calcite users (phytoplankton, foraminifera and coccolithophore algae), and aragonite users (corals, shellfish, pteropods and heteropods).

The photo below left shows healthy specimens of calcifying phytoplankton *Gephyrocapsa oceanica*. The photo below right shows the damage to the same creature under conditions expected by the end of the century.

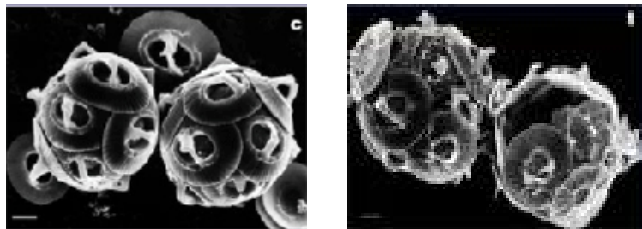


Fig 3: Healthy phytoplankton; same species with malformed shell plates as a result of damage by seawater with simulated end of century chemistry.

Source: Nature, Reduced Calcification of Marine Phytoplankton in Response to Increased Atmospheric CO₂, Issue 407 p.364 -367

It is often said that a picture is worth a thousand words.

Research in the Southern Ocean provides evidence that the formation of foraminifera shells is already being affected. Even though these creatures use calcite, which is less soluble than aragonite, there are already clear signs of physical damage. According to Dr. Will Howard of the Antarctic Climate and Ecosystems Cooperative Research Centre in Hobart, shells of one species of foraminifera (*Globigerina bulloides*) are 30 to 35 percent thinner than shells formed prior to the industrial period. [vi]. The photo below left shows a pre-industrial exoskeleton of this species obtained from sea-floor sediment. The photo below right shows an exoskeleton of a live specimen of the same species obtained from the water column in the same area in 2007. These stunning images were obtained using an electron microscope. (An interview with Dr. Howard was broadcast on the Catalyst television program). [vii] What is staggering is the amount of erosion in the right image compared to the left. The right sample looks porous with larger holes and a 10-fold increase in their number. These and creatures like them are at the base of an ocean food chain, and they are already seriously damaged. If they are lost, it is not just biodiversity we are losing, but our food supply as well.

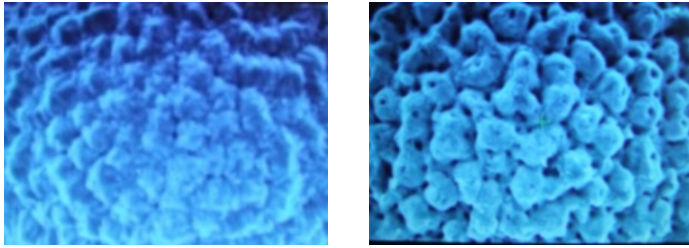


Fig 4. Pre-industrial and current samples of *Globigerina bulloides* from same location. Latter shows extensive erosion with a ten-fold increase in holes.

Source: Australian Broadcasting Corporation, *Ocean Acidification – The Big Global Warming Story*, 13 September 2007

The implications of all of this are disturbing. For corals to absorb aragonite from seawater, the latter needs to be saturated in this mineral.

Now a report from NOAA scientists found large quantities of water undersaturated in aragonite are already upwelling close to the Pacific continental shelf from Vancouver to northern California [v]. Although the study only dealt with the area, the authors suggest that other shelf areas may be experiencing similar effects.



For corals like those in Australia's Great Barrier Reef, the outlook is grim. They are threatened with destruction on two fronts, both caused by CO₂ emissions. Not only do increased ocean temperatures bleach coral by forcing them to expel the algae which supplies them with energy (see photo at left) [viii], but increased ocean CO₂ reduces the availability of aragonite from which reefs are made.

It is time to wake up. Our planet is dying. I urge you to find the time to view a 20 minute documentary on the problem of ocean acidification produced by the international Natural Resource Defence Council. Simply go to: www.acidtestmovie.com

Fig 5. Coral killed by above average ocean temperatures.

References and Notes

[i] pH is a measure of the acidity or alkalinity of a solution. It uses a negative logarithmic scale where a decrease of 1.0 units represents a 10-fold increase in acidity. In their natural state prior to industrialization, the oceans were slightly alkaline with a pH of 8.2 (see reference iii). Pure water has a pH of 7.0.

[ii] Feely R., Doney S., Cooley S. (2009). Present Conditions and Future Changes in a High-CO₂ World. *Oceanography* 22, 36-47

[iii] Australian Antarctic Division, Ocean Acidification and the Southern Ocean, available at <http://www.aad.gov.au/default.asp?casid=33583>

[iv] Feely, Doney and Cooley, op. cit, using Mauna Loa data from the US National Oceanic and Atmospheric Administration and Aloha data from the University of Hawaii.

[v] Feely RA, Sabine CL, Hernandez-Ayon JM, lanson D, Hales B (June 2008). Evidence for upwelling of corrosive "acidified" water onto the continental shelf. *Science* 320 (5882): 1490–2, available at <http://www.sciencemag.org/content/320/5882/1490>

[vi] Inter Press Service, Acid Oceans Altering Marine Life, available at <http://ipsnews.net/news.asp?idnews=46055>

[vii] Australian Broadcasting Corporation, Ocean Acidification – The Big Global Warming Story, downloadable at <http://www.abc.net.au/catalyst/stories/s2029333.htm>

[viii] Great Barrier Reef Marine Park Authority, What is Coral Bleaching?, available at http://www.gbrmpa.gov.au/corp_site/key_issues/climate_change/climate_change_and_the_great_barrier_reef/what_is_coral_bleaching

Intermediate rebuttal written by alan_marshall

Update July 2015:

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

Additional videos from the MOOC

Expert interview with [Annamieke Van De Heuvel](#)

Expert interview with [Charlie Veron](#)

Expert interview with [Ove Hoegh-Guldberg](#)



Skeptical Science explains the science of global warming and examines climate misinformation through the lens of peer-reviewed research. The website won the Australian Museum 2011 Eureka Prize for the Advancement of Climate Change Knowledge. Members of the Skeptical Science team have authored peer-reviewed papers, a [college textbook on climate change](#) and the book [Climate Change Denial: Heads in the Sand](#). Skeptical Science content has been used in university courses, textbooks, government reports on climate change, television documentaries and numerous books.



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