

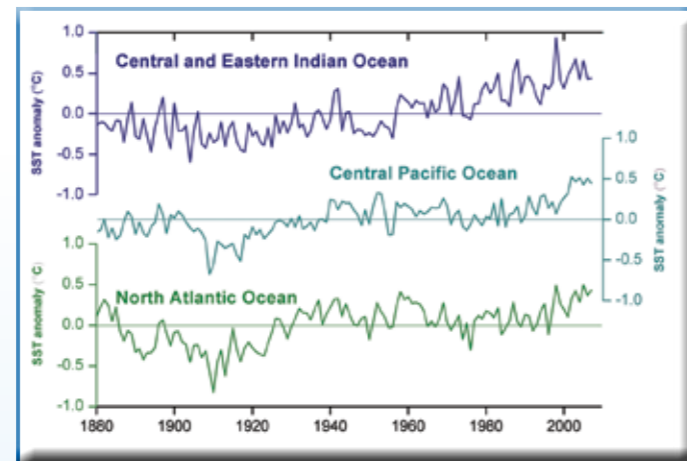
WARMER WATERS CAUSE CORAL BLEACHING AND DEATH

The most dramatic recent damage to coral reefs occurred in 1998 when global-scale coral bleaching and subsequent mortality devastated reefs around the world. It was followed in 2005 by unprecedented levels of bleaching-related mortality in parts of the Caribbean. Such events have become increasingly common since the early 1980s when atmospheric CO₂ concentrations reached 320 parts per million (ppm); it is now more than 385 ppm and is predicted to reach 450 ppm by 2030 to 2040.

In 1997/98, massive El Niño and La Niña climate oscillations resulted in raised sea surface temperatures (SSTs) throughout the Indian Ocean, the wider Caribbean and Pacific Ocean. About 16% of the world's coral reefs were effectively destroyed in just 9 months. For example, more than 90% of the corals on many reefs in the Maldives and Palau were lost. Since then, some reefs have recovered, but many have not because sediment and nutrient pollution, over-fishing, mining of sand and rock and coastal development have inhibited recovery.

Then in 2005, severe ocean warming resulted in coral bleaching and mortality that was far more damaging than anything previously experienced in the Northeastern and Eastern Caribbean. Some reefs lost more than 50% of their live coral cover; 2005 also broke storm records in the wider Caribbean region.

Sea surface temperatures just 1–2°C above the normal summer maximum for a few weeks under clear tropical skies will cause corals to bleach; they will die if these conditions persist. The higher temperatures and solar radiation disrupt photosynthesis in the coral's symbiotic algae (*zooxanthellae*) and result in the production of toxic free oxygen radicals that cause the corals to eject the algae. These stressed corals have lost their major source of energy and are effectively



Ocean temperatures show distinct warming in all oceans over the last 50 years as measured by the National Oceanic and Atmospheric Administration of USA

starving. Some corals can regain their algae and recover; but the increased stress often results in lethal coral diseases or reduced coral reproduction and growth during the next year.

Global temperatures are steadily rising and have increased by 0.74°C over the lands and oceans since 1900. Tropical reef-building corals are now about 1°C closer to their upper thermal tolerance limits than they were 100 years ago. Bleaching could become an annual event in 20 years with predicted CO₂ concentration of around 450 ppm. The consensus of leading scientists assembled by the UK Royal Society in 2009 was that atmospheric CO₂ concentrations need to be “significantly below 350 ppm” for the long-term viability of coral reefs.

Prevention of coral bleaching and death is needed to sustain local food sources and economies in coral-reef dependent states such as Palau, Bonaire, and Seychelles; Palau experienced a 5-10% decrease in tourism income after the bleaching in 1998.



RIISING CO₂ IN SEAWATER WILL REDUCE CORAL CALCIFICATION

Another major impact of increasing CO₂ emissions is ocean acidification. This is a well known chemical reaction when CO₂ dissolves in seawater to make a weak acid or marine ‘soda water’. The oceans absorb 25% to 33% of all the CO₂ added to the atmosphere each year, leading to the formation of carbonic acid and an increase in acid ions, which have already increased by 30%.

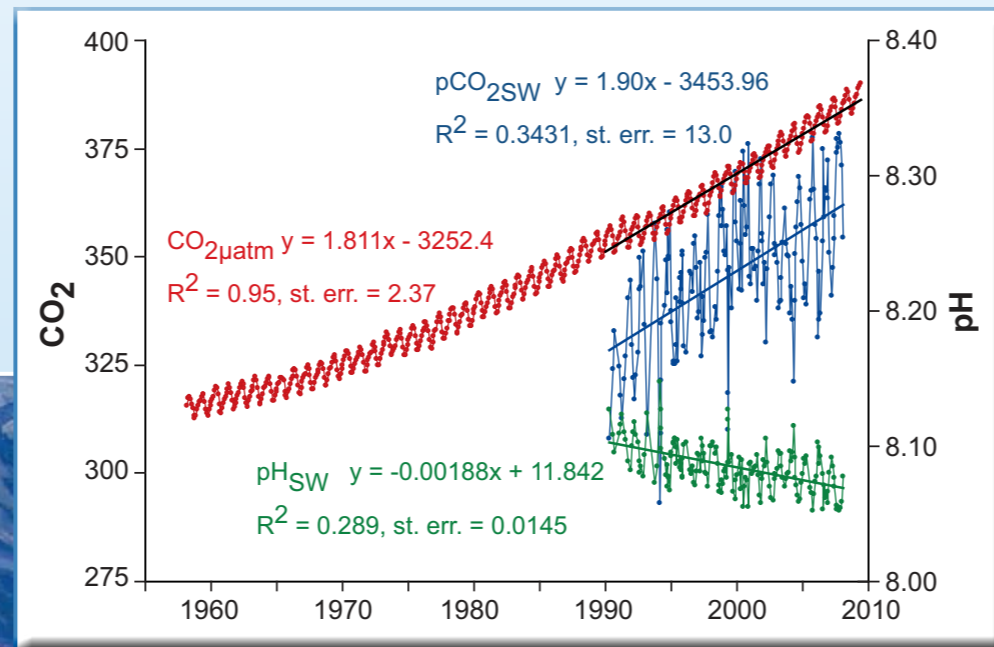
The average pH in the upper layers of the ocean (where most ocean life thrives) has dropped from approximately 8.21 to 8.10 units since the industrial period. The acid ion concentration in the surface layers of the ocean is already the strongest in 800,000 years, and probably 20 million years; if atmospheric CO₂ concentrations continue to increase to 800 ppm, surface ocean pH will decrease further by 0.3 - 0.4 pH units and severely disrupt calcification.

Ocean acidification causes a suite of chemical changes in seawater, some of which have been shown to affect marine life. Of special concern to coral reefs is the decrease in the carbonate ion concentration, because this reduces the capacity of corals and many other calcifying organisms to make strong calcium carbonate skeletons. Reefs growing in naturally lower

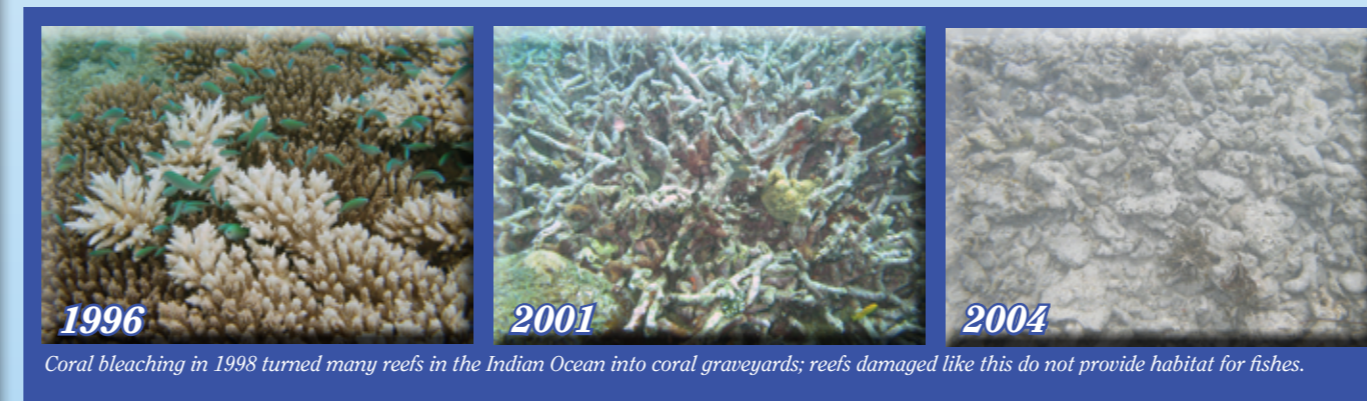
pH environments are more fragile because they have less of the ‘cement’ that binds reefs together.

In experiments simulating pH conditions for the year 2050 (550 ppm or double the CO₂ in pre-industrial times), coral skeletal growth decreases by 20–50%. Weakened corals will crumble in the face of storm waves, thereby destroying much of the habitat for other reef biodiversity, including food fish. Under more extreme acid conditions, some corals could completely lose their skeletons. Coral calcification has probably already decreased by 15%, due to increasing ocean acidification and more heat stress and bleaching. Ocean acidification also may increase the susceptibility of corals to bleaching due to warmer temperatures.

Crustose coralline algae are also important reef-builders as they ‘cement’ coral reef rubble together; these are particularly vulnerable to ocean acidification because they secrete a more soluble form of calcium carbonate. At 450 ppm, these coralline algae will not calcify and the reduced calcification rates will shift most reefs from net growth to net dissolution by 2050. The combined effects of ocean acidification and bleaching will be devastating for all the other animals and plants that depend on coral reefs for a habitat. Moreover this will be particularly disastrous for people living on low lying coral islands.

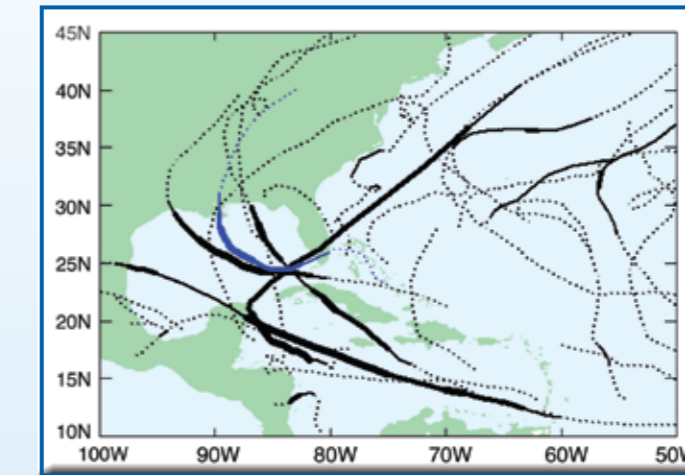


As CO₂ (red) increases in the atmosphere, more will dissolve in the oceans (blue) and lower the pH (green = more acidity) thereby reducing calcification for corals and other biota.



STORMS, CURRENTS AND SEA LEVEL RISE

Rises in global temperatures increase the energy in the oceans and atmosphere that can generate tropical storms (hurricanes, cyclones, typhoons). Present predictions do not suggest a major increase in the number of storms, but predict an increase in the strength of storms with more category 4 and 5 severe cyclones. These will wreak havoc on coral reefs and islands, for example, severe cyclone Hamish smashed 70% of the corals along a 500 km strip of the southern Great Barrier Reef in 2009.



The 26 named tropical storms in the wider Caribbean between July and November, 2005, included Hurricane Katrina (blue line) that devastated New Orleans among the 13 hurricanes (thick lines). But there were no hurricanes in the Lesser Antilles where coral bleaching was most extreme.



Sea level rise threatens the existence of low lying island countries; this is Kiribati during a storm in 2005.

