Be Prepared:
The Oceans in a +2°C World

A fact sheet on Climate Change and the Ocean

A global average temperature increase of 2°Celsius (C), the stated policy goal of many nations, will have a profound impact on the oceans and coasts, and consequently global society. It is difficult to translate this temperature increase to exact atmospheric carbon dioxide (CO_2) concentrations, but 450 parts per million (ppm) will likely lead to more than 2°C global temperature increase, and possibly up to 4°C.

The Role of the Ocean

The ocean has played a critical buffering role in climate change, by absorbing heat and carbon dioxide that would have otherwise contributed to global warming. Since the Industrial Revolution, the ocean has absorbed approximately one-half of the human-released CO_2 (about 525 billion tons).

Ocean Acidification

By absorbing massive amounts of carbon dioxide, the pH (a measure of acidity) of ocean surface waters has dropped by 0.1 since the Industrial Revolution. The pH scale is exponential and a change of this proportion is equivalent to an increase in acidity by approximately 30%. As CO_2 dissolves in the ocean, seawater becomes more acidic and the amount of dissolved carbonate available for calcium carbonate shell and skeleton formation—important to corals, plankton and shellfish—decreases. With increasing ocean acidity, the rate at which reef-building corals produce their skeletons decreases. If carbonate concentrations fall too low, corals may start to dissolve (See Figure 1). In addition, the survival of young fish may decrease and it will become harder for some plankton to maintain their protective shells. Plankton form the base of the food chain for most ocean ecosystems and provide about half the oxygen we breathe.

Ocean acidification can also lead to less sound absorption—making the oceans a noisier environment—[i] and may lead to acidosis, a buildup of acidity in the body fluids of marine organisms, potentially leading to lowered immune response, metabolic decline, reproductive difficulties, respiratory problems and even death.

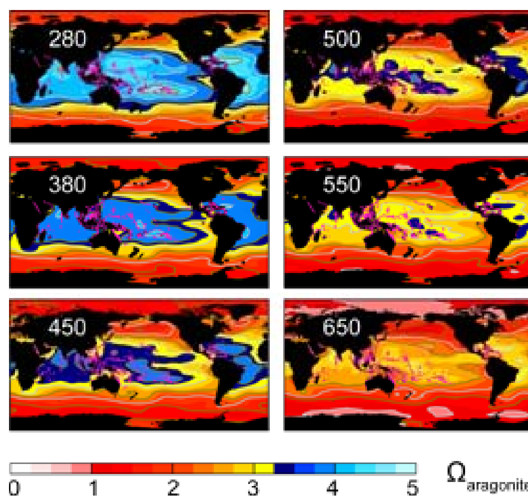

Figure 1. Calcium Carbonate Availability for Corals

The availability of aragonite, a form of calcium carbonate used by corals, will change as atmospheric carbon dioxide concentrations increase. The blue colors are areas with a high enough aragonite concentration for corals to grow. At 450ppm, the waters surrounding the Great Barrier Reef are no longer conducive to coral growth. Hoegh-Guldberg, et al. 2007

[i] K. C. Hester, E. T. Peltzer, W. J. Kirkwood, and P. G. Brewer (2008) Unanticipated consequences of ocean acidification: A noisier ocean at lower pH. 2008. Geophysical Research Letters 35, 31

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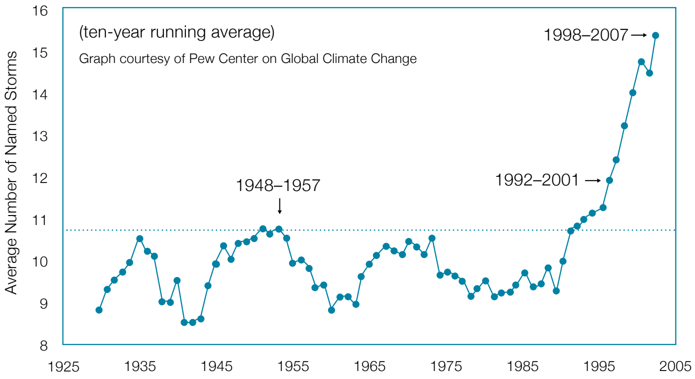
Figure 2. Bleached corals in the Southern Great Barrier Reef in January 2002. Increasingly, corals are dying after bleaching events, thus affecting their role as habitat for hundreds of species including fish. (Ove Hoegh-Guldberg, Centre for Marine Studies, The University of Queensland)

Ocean Warming

Ocean temperatures, like their atmospheric counterparts, are increasing. The ocean, which covers 70% of the planet, stores much of the heat. The absorption of much of Earth's "excess" heat from human-produced CO_2 has caused the ocean to undergo a sustained warming trend for the last 50 years.

NOAA's National Climate Data Center (NCDC) recorded the warmest global ocean surface temperature on record in July 2009, beating the previous record established in 1998.

Annual Frequency of North Atlantic Tropical Storms



Ocean warming has several major consequences:

- Warming ocean waters fundamentally change habitat, causing **species to move** to find cooler waters.
- Finally, thermal expansion — the expansion of warmer water — will lead to **sea level rise** (see next section).
- Warming of surface waters can also increase the strength of water column **stratification**, when the warm oxygen-rich, nutrient-poor water floats on top of colder, denser, nutrient-rich ocean water. The greater the temperature difference, the more resistant these two layers are to mixing. Reduced mixing means less nutrients for plankton to grow within the sunlit zone, reducing the amount of food available for the oceanic food web.
- Warmer sea surface temperatures in the tropical oceans will likely lead to (1) longer **storm** seasons, and (2) more frequent, stronger storms.
- Mass coral **bleaching** events are closely associated with prolonged elevated sea surface temperatures (See figure 2). Coral bleaching affects the ability of coral to grow and reproduce, and may increase their susceptibility to disease. 2°C rise in tropical sea temperatures will cause coral bleaching to occur on a yearly basis, leading to their disappearance from tropical reef systems. This will have devastating consequences for dependent species and an estimated 500 million people that depend on coral reefs for their daily food and income.

Sea Level Rise

There are two major driving forces behind sea level: global ice volume and thermal expansion.[ii, iii, iv] Thermal expansion is responsible for about 40% of the sea level rise between 1961 and 2003, while reduction in global ice volume contributed to approximately 60% of this rise.[v] Both driving forces are impacted by temperature — the warmer the earth becomes, the more sea level will rise.

Sea level rise is hard to predict, mainly because of uncertainty in the rate and magnitude of future changes in the Greenland and Antarctic ice sheets. According to the 2009 Copenhagen Climate Congress Synthesis Report, "the new observations of the increasing loss of mass from glaciers, ice caps and the Greenland and Antarctic ice sheets lead to predictions of global mean sea level rises of 1 m (±0.5 m) during the next century."[vi] Currently 160 million people live less than 1 meter above sea level.

Figure 3. Iceberg, East Antarctic Margin (© Rob Dunbar)

Typhoon Sinlaku moving through the North West Pacific, south of Japan. Among the impacts of climate change are increased tropical storm frequency and intensity. (Jacques Descloitres, MODIS Land Rapid Response Team, NASA/GSFC)

ii R. B. Alley, The Two-Mile Time Machine: Ice cores, abrupt climate change, and our future. (Princeton University Press, Princeton, 2000), pp. 229.

iii C. Cabanes, A. Cazenave, C. Le Provost, Science 294, 840 (2001).

iv N. L. Bindoff, et al., in Climate Change 2007: The Physical Science Basis. Contributions of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller, Ed. (Cambridge University Press, Cambridge, 2007).

v C. M. Domingues et al., Nature 453, 1090 (2008).

vi University of Copenhagen. Synthesis Report from Climate Change Global Risks, Challenges, & Decisions, Copenhagen 10–12 March, 2009. Retrieved from www.climatecongress.ku.dk

Altered Currents

Global climate change alters wind regimes, precipitation, temperature and salinity patterns, all of which in turn affect ocean circulation.

Thermohaline circulation is the conveyer belt-like large-scale process by which waters are driven across the planet, propelled by temperature and density gradients. Cold, dense polar water sinks to the deep ocean, travels across the ocean basins towards the equator, where they are eventually upwelled to the surface. Warmer, less dense, tropical waters are then drawn to polar latitudes along the surface, where heat is transferred to the atmosphere, causing the water to become cold and dense — thus completing the conveyor belt. Melting of polar ice could reduce the salinity and thus density of polar waters, which could weaken the rate at which this water sinks — altering the movement of heat around the globe.

Upwelling is a wind-driven process that brings cold, nutrient rich waters up from the depths of the ocean to light-penetrating surface waters where phytoplankton (small floating plants that form the base of most ocean food chains) grow. Due to changes in global air temperatures over land and ocean, as well as increased temperature variation, atmospheric pressure gradients that drive the strength of winds over the ocean are being altered. The altered wind is affecting the timing and intensity of upwelling. Many marine animals time their breeding and migrations with the influx of nutrients and growth of prey populations. Disruptions to these finely tuned processes may lead to starvation and reproductive failure.

Oxygen Minimum Layer (OML Expansion)

The OML is a naturally occurring layer of water with low levels of oxygen that make it difficult for many animals to survive. The depth of the upper boundary of the OML ranges from 200–600m below the surface. Several recent studies indicate that the OML in many areas has expanded vertically since 1960[vii]. This means the upper boundary has moved closer to the surface, in some cases by as much as 100 m.

There are currently two primary explanations to explain worldwide changes in the OML. First, climate change and its impact on currents, winds and stratification may be causing the shift. Second, the large increase in deposition of atmospheric nitrogenous gasses from agricultural fertilization and fossil-fuel emissions may be working in concert with climate change to expand the OML.

Chance of Reaching Two Degrees Limit

According to a recent study,[viii] to have a 25% chance of achieving the 2°C goal, global emissions for 2000–2050 must be limited to 1000 Gigatons of carbon. At current emission rates, we will reach this limit by 2030.[ix] The atmospheric concentration of CO_2 in 2009 is 387 parts per million (ppm) which is higher than at any time in the last 800,000 years,[x] and potentially the last 14 million years.[xi] Rather than being on the road to emission reduction, the rate at which we are emitting is increasing. In the 1990s, the emission rate increased 1% each year; from 2000–2008, the annual emissions rate increase was 3.4%.

vii Whitney FA, Freeland HJ, Robert M, Prog. Oceanography 75,179–199 (2007); Monterey Bay Aquarium Research Institute,Annual Report: State of Monterey Bay 2008: 31–33 (2008) Available online at: www.mbari.org/news/publications/ar/2008ann_rpt.pdf; S.G. Bograd, et al. Geophys Res Lett 35 L12607, doi:10.1029/2008GL034185 (2008); L. Stramma, G.C. Johnson, J. Sprintall, V. Mohrholz, Science 320, 655–658 (2008).

viii Meinshausen, M. et al., Nature. 458, 1158–1162 (2009).

ix I. Allison, et al., The Copenhagen Diagnosis, 2009: Updating the World on the Latest Climate Science.The University of New South Wales Climate Change Research Centre (CCRC), Sydney, Australia, 60pp (2009).

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Graphic Citations

Hoegh-Guldberg, O. et al. 2007. Coral Reefs Under Rapid Climate Change and Ocean Acidification. Science 318, 1737.

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