ON OCEANS AND CLIMATE CHANGE

Dr Pushp Bajaj
23 July 2020

The ocean is and always has been essential to life on planet Earth. In fact, the ocean is where the very first life forms emerged on the planet. Even today, the world's oceans support nearly all life on Earth either directly or indirectly. In the current world order, every coastal nation's economy relies heavily on its surrounding ocean and the living and non-living ocean resources. The lesser appreciated fact, however, is that the oceans also regulate our climate, they are important components of the carbon cycle and the water cycle, and they are responsible for transporting heat across the planet through global water circulation patterns. Due to current anthropogenic climate change, the ocean is undergoing a remarkable chemical and physical transformation that will have profound implications for marine life, Earth's climate, coastal human populations, and ocean economies around the world.

This article seeks to provide an overview of how the global ocean is closely interlinked with climate change, how it is changing dramatically, and what the consequences of these changes will be for marine life and, in turn, for the billions of people that depend on marine life. The article will also discuss the importance of sustainable management and conservation of marine and coastal ecosystems, so as to restore the health of the ocean and, in the process, contribute to the mitigation of climate change.

The importance of the oceans for sustenance of human life cannot be overstated. Microscopic plants in the oceans, called phytoplankton, form the base of the marine food-chain. They consume carbon dioxide (CO_2) through photosynthesis and generate oxygen, in the same way as do land-based plants. According to scientific estimates, phytoplankton produce as much as 80 per cent of the world's oxygen and feed everything from microscopic zooplankton to small fish, and invertebrates to multi-tonne whales.[1] The oceans also regulate the global climate by participating in the carbon cycle, the water cycle, and the heat cycle, the last-named through ocean circulation patterns that transport heat across the planet. For instance, changes in temperature and currents of the Indian Ocean regulate the Indian monsoon, which supplies over 70 per cent of India's annual rainfall.[2] At the global scale, the Atlantic Meridional Overturning Circulation, which is a large system of ocean currents driven by differences in temperature and salinity of water, carries warm ocean water from the tropics to the North Atlantic, evenly

[1] Sarah Witman, "World's Biggest Oxygen Producers Living in Swirling Ocean Waters", *Eos*, 13 September 2017. https://eos.org/research-spotlights/worlds-biggest-oxygen-producers-living-in-swirling-ocean-waters
[2] Ramesh Kumar Yadav, "Emerging Role of Indian Ocean on Indian Northeast Monsoon", *Climate Dynamics* 41, 105-116 (2013). https://doi.org/10.1007/s00382-012-1637-0

distributing heat across the world's oceans and maintaining the climate in the Northern Hemisphere.[3]

The Ocean as the First Line of Defence Against Climate Change

In addition to the uptake of carbon dioxide by phytoplankton, the ocean also absorbs carbon by simply dissolving atmospheric CO_2 in the water. Through these two processes, the global ocean acts as a massive carbon sink, absorbing CO_2 from the atmosphere, just as is the case with forests and soils. More than a third of all human-caused (anthropogenic) carbon emissions end-up in the ocean. When CO_2 is dissolved in water, it forms an acid called carbonic acid. Therefore, as more and more CO_2 is absorbed by the oceans, they are becoming more and more acidic. This is commonly referred to as 'ocean acidification'. According to a Special Report by the United Nations' Intergovernmental Panel on Climate Change (IPCC) on *"The Ocean and Cryosphere in a Changing Climate"*, published in 2019, the pH (a measure of acidity) of open ocean surface-water has been declining at the rate of 0.017-0.027 units per decade since the late 1980s.[4] The current rate of acidification is faster than anything experienced during the last 300 million years.[5] The same report projects that if carbon emissions continue at the current rate, the pH of ocean surface-water will likely drop by 0.287-0.291 units by 2081-2100, relative to 2006-2015 levels, with the Arctic and north Atlantic ocean-basins experiencing the largest changes.

In addition to acting as a carbon sink, the ocean also acts as an enormous heat sink. It absorbs as much as 90 per cent of the excess heat generated by the increasing greenhouse gases in the atmosphere. Data records maintained by the USA's National Oceanic and Atmospheric Administration (NOAA) show that the "ocean heat content" has been rising relentlessly since 1970 (see **Figure 1**). Because of the sheer size and depth of the ocean and the amount of water that is available, it takes a long time to heat up all the ocean. Consequently, the heat-absorption capacity of the oceans is huge. Without the oceans, all this energy would have gone into the atmosphere and greatly increased temperatures around the planet. In other words, the ocean has significantly slowed down global warming in the atmosphere and over land. This phenomenon is well established within the scientific community and is sometimes referred to as "climate inertia". There is a lag between the time that a CO_2 molecule is emitted into the atmosphere and the time when its full warming potential is realised. The main reason for this time lag is because the upper ocean waters initially absorb most of the added heat, which then gradually mixes with deeper waters and eventually comes to equilibrium with the atmosphere. The entire process can take many decades and even up to a century or more.

---

[3] "What is the Atlantic Meridional Overturning Circulation?", UK Met Office. https://www.metoffice.gov.uk/weather/learn-about/weather/oceans/amoc

[4] Nathaniel L. Bindoff et al, "Changing Ocean, Marine Ecosystems, and Dependent Communities", in IPCC Special Report on the Ocean and the Cryosphere in a Changing Climate, eds Hans-Otto Pörtner et al, (In Press, 2019). https://www.ipcc.ch/srocc/chapter/chapter-5/

[5] "Ocean Acidification", IUCN Issues Brief, International Union for Conservation of Nature (IUCN). https://www.iucn.org/resources/issues-briefs/ocean-acidification

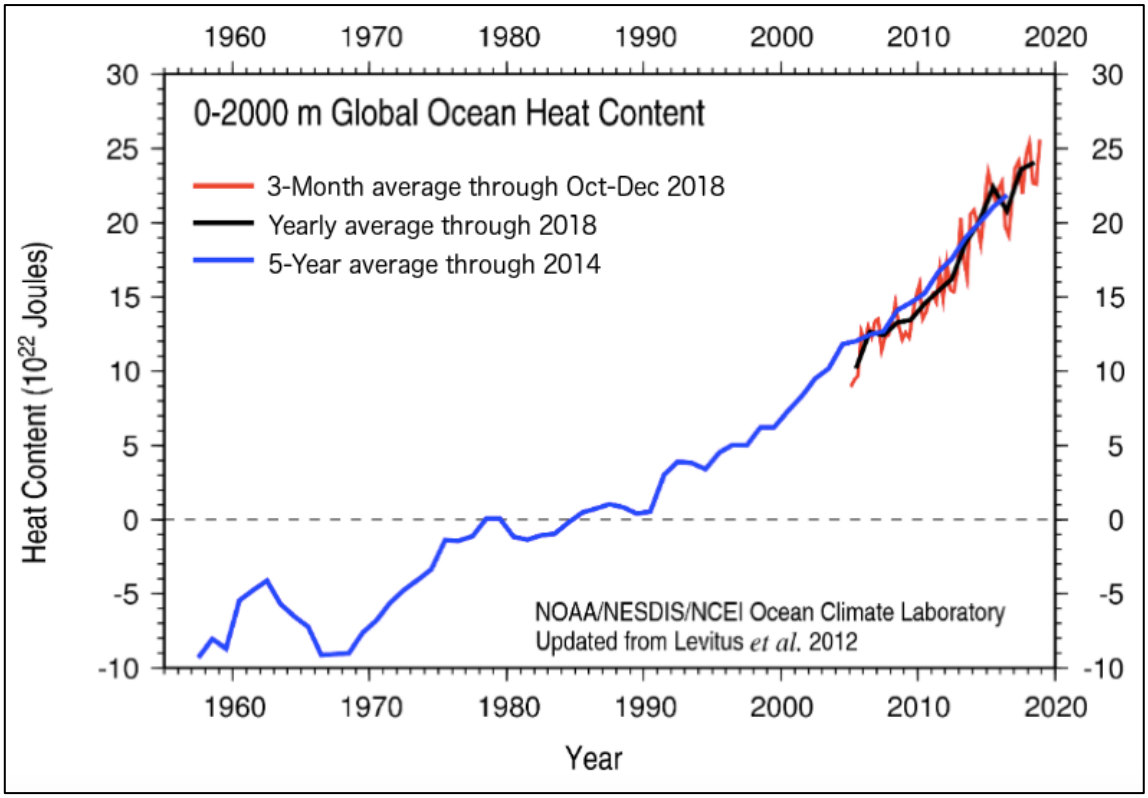

Fig 1: Time series of global ocean content up to 2000 m depth
Source: US National Oceanic and Atmospheric Administration (NOAA)

This delayed response of the climate system can be further established by considering the trends in global average temperature and CO_2 levels in the atmosphere. **Figure 2** shows the CO_2 concentration (in blue) in the atmosphere over the past 800,000 years, along with the polar temperature (in red) as an indicator of the average climatic conditions. The close relationship between CO_2 concentration and temperature is quite evident from the graph. The peaks and the valleys align very closely between the two, until one arrives towards the end of the graph, which represents the present time. Clearly, there is a sharp, unprecedented (at least in the past 800,000 years) rise in CO_2 concentration, undoubtedly driven by emissions from human activities, in the time-period following the industrial revolution. The temperature curve, however, appears to have not yet caught up with the sudden meteoric rise of CO_2. In 2014, atmospheric CO_2 concentration crossed the crucial threshold of 400 ppm (parts per million). The last time atmospheric CO_2 levels were that high was around 5 to 3 million years ago, during what is known as the Pliocene Epoch, when the global average temperature was 2-3° C higher than it is today. CO_2 levels in the atmosphere are still increasing at an accelerating pace.

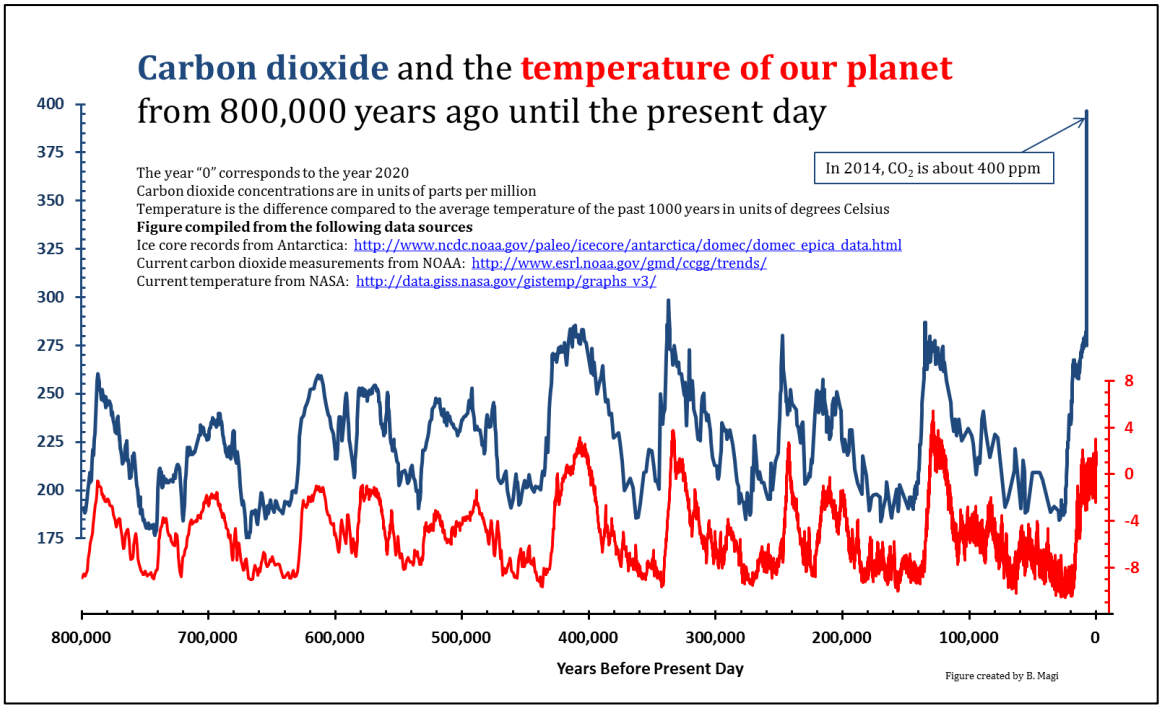

Fig 2: Time series of atmospheric CO2 concentration and average temperature from 800,000 years ago to 2014
Source: Image created by Brian Magi. Data sources listed in the image

To the best of current scientific understanding, if the CO_2 concentration does not drop significantly, the global average temperature will eventually reach levels similar to those that prevailed in the Pliocene Epoch. This implies that there is more global warming that is still "in the pipeline" from the carbon that has already been added to the atmosphere. It is difficult to predict how and when the climate system will attain equilibrium and reach those temperature levels. In this context, the ocean has provided humanity the crucial gift of time. We could, at least in principle, get the atmospheric CO_2 levels down to a safe level before the equilibrium response is reached. This is, however, a double-edged sword, because if we do not account for this delayed response, it may leave us complacent and push us beyond the point-of-no-return. In any case, while that may appear, at first glance, to be a blessing, the ocean's ability to absorb CO_2 and heat has severe implications for marine plant and animal species.

The Cost that the Ocean Pays

The above-mentioned changes in the chemistry and physics of the oceans have drastic and widespread impacts on marine ecosystems. Ocean acidification is particularly harmful to marine species that have shells or skeletons made of calcium, such as corals, and molluscs such as oysters and mussels, as rising ocean acidity causes such shells to dissolve and also hinders their formation in the first instance. The combined effects of increasing ocean temperatures, rising acidity and declining oxygen levels are causing mass coral bleaching, mass die-offs, changes in migration patterns, reproductive cycles, and, the geographical distribution of marine species (both plants and animals). Phytoplankton, for instance, are being knocked out of balance by climate-change impacts, with some species outperforming others, leading to dramatic changes in

regional distributions.[6] As mentioned earlier, phytoplankton form the base of the food chain, and any changes in their distribution will have ripple-effects across the entire marine food web. According to a recent study, climate-change impacts are also making phytoplankton less efficient at sequestering carbon from the atmosphere, which could significantly reduce the overall carbon sink capacity of the ocean.[7]

The 2019 UN IPCC Special Report on *"The Ocean and Cryosphere in a Changing Climate"*, concludes that marine heat-waves are becoming more frequent, extensive, and intense, in most regions of the world, due to continually rising upper ocean temperatures.[8] A marine heat-wave refers to a period of abnormally high ocean temperatures over days or months. It can extend across thousands of kilometres and can penetrate the oceans to depths of several hundred metres. Projections based upon carefully generated climate-models suggest that at a global level, the intensity of marine-heat-waves and the number of days over which these marine-heat-wave last per year, will continue to increase throughout this century, that too, at an accelerating pace. Thus, many parts of the oceans may reach a state where a near-permanent heat-wave is experienced (compared to the 1982-2005 average conditions).[9]

Coral reefs provide essential habitat for thousands of marine species and support nearly a quarter of all marine life. These reefs are particularly vulnerable to heat waves. The Great Barrier Reef, which lies along the north-eastern coast of Australia, has already suffered three severe marine heat-waves in the last five years (2015-2016, 2016-2017, and 2019-2020), all of which led to mass coral-bleaching.[10] Indian coral reefs in the Gulfs of Mannar and Kachchh, the Palk Bay, and the Andaman and the Lakshadweep Seas, have experienced as many as 29 widespread bleaching-events since 1989. Future projections suggest that all the world's coral reefs may be lost by 2100 if we continue with business-as-usual.[11]

Marine organisms are responding to climatic changes in a variety of different ways, depending on their habitats, geographic affinities, and biological traits. The most common responses are changes in migration patterns and geographical distribution. On land, species tend to move northward to cooler regions in response rising temperatures. In the ocean, marine animals could move both horizontally to different locations and vertically to different depths, to avoid unfavourable seawater temperatures. Other responses include changes in physiological features (such as size), growth rates, and reproduction cycles. For instance, in recent decades, the oil

---

[6] Jennifer Chu, "Ocean Acidification May Cause Dramatic Changes to Phytoplankton", *MIT News*, 20 July 2015. http://news.mit.edu/2015/ocean-acidification-phytoplankton-0720

[7] Katherina Petrou et al, "Acidification Diminishes Diatom Silica Production in the Southern Ocean", *Nature Climate Change* 9, 781-786 (2019). https://doi.org/10.1038/s41558-019-0557-y

[8] Matthew Collins et al, "Extremes, Abrupt Changes and Managing Risk", in IPCC Special Report on the Ocean and the Cryosphere in a Changing Climate, eds Hans-Otto Pörtner et al, (In Press, 2019). https://www.ipcc.ch/srocc/chapter/chapter-6/

[9] Eric C. J. Oliver et al, "Projected Marine Heatwaves in the 21st Century and the Potential for Ecological Impact", *Frontiers in Marine Research* 6 (2019). https://www.frontiersin.org/articles/10.3389/fmars.2019.00734/full

[10] "2020 Marine Heatwave on the Great Barrier Reef", Bureau of Meteorology, Australian Government (2020). http://www.bom.gov.au/environment/doc/2020-GBR-marine-heatwave-factsheet.pdf

[11] Jordan Davidson, "Coral Reefs Could Be Completely Lost to the Climate Crisis by 2100, New Study Finds", *EcoWatch*, 20 February 2020. https://www.ecowatch.com/coral-reefs-climate-crisis-predictions-2645201373.html

sardine and the Indian mackerel, two of the most important types of commercial fish in India, have, due to increasing temperatures, extended their reach to higher (northerly) latitudes, where more hospitable conditions are experienced. Fish typically have a narrow range of preferred temperatures. While the movement of the oil sardine and the Indian mackerel has, thus far, been an "extension" of geographic reach and not really a "shift", if temperatures increase beyond the physiological optimum of the fish in the southern latitudes, then entire fish populations could shift northwards permanently. Therefore, depending on the species and the magnitude of environmental change, the area that it occupies could expand, shrink, or be relocated.[12]

The full extent of these impacts on marine species and their ecosystems is difficult to assess due to lack of long-term data records of populations of different species, as also regional climatic and oceanographic parameters. At longer timescales, such geographic redistributions of marine plant and animal populations could fundamentally change the structure and function of marine ecosystems. Naturally, these changes will have a significant impact on the fisheries industry and on coastal populations that rely heavily on fishes as a primary food source. Most likely, some regions will benefit at the expense of other regions, leading to economic competition and economic-migration of coastal communities. Fishers will have to adapt accordingly, whenever possible, by extending their reach, acquiring new equipment and resources, or focussing on other fish that may now become more abundant in their region.

Ocean Conservation to Mitigate Climate-Change

Sustainable management and conservation of endangered species and habitats is essential to maintain the overall health of the ocean and marine life. Since climatic changes will impact different species differently, conservation efforts must be preceded by exhaustive 'vulnerability assessments' at the regional-, national-, and global-level, to identify the most vulnerable species/regions. This would require expanding monitoring capacity and maintaining data records, not only of species distributions and behaviour, but also of climatic changes in the oceans, to draw correct correlations and make informed decisions. Moreover, as climate-change impacts intensify in the future, it will become even more important to limit the stresses from human exploitation in terms of marine pollution, overfishing, and, Illegal, Unreported, and Unregulated (IUU) fishing. In this regard, Marine Protected Areas (MPAs) must be established, particularly around vulnerable areas, to allow under-stress habitats to recover and enhance resilience.

When it comes to ocean conservation, it is imperative to adopt a holistic approach and protect entire ecosystems to protect individual species. Coastal ecosystems such as coral reefs, seagrass meadows, mangrove forests, and wetlands, must all be protected as they provide critical habitats for vast numbers of marine species. Protecting and restoring these ecosystems will, in turn, help in mitigating climate change, as they absorb and sequester large quantities of carbon dioxide from the atmosphere, contextually referred to as 'blue carbon'. Moreover, they act as highly

[12] Bimal Mohanty et al, "The Impact of Climate Change on Marine and Inland Fisheries and Aquaculture in India", in Climate Change Impacts on Fisheries and Aquaculture: A Global Analysis, eds Bruce F. Phillips and Mónica Pérez-Ramirez (Wiley-Blackwell, 2017).

effective natural defences against sea-level rise and cyclonic storms. Therefore, the conservation of marine and coastal ecosystems must be central to any and all climate-change mitigation and adaptation strategies.[13]

About the Author:

Dr Pushp Bajaj is an Associate Fellow at the NMF. His current research focusses upon the impact of climate-change on India's holistic maritime security. He may be contacted at climatechange2.nmf@gmail.com.

[13] Jean-Pierre Gattuso et al, "Ocean Solutions to Address Climate Change and Its Effects on Marine Ecosystems", *Frontiers in Marine Science* 5, 337 (2018). https://doi.org/10.3389/fmars.2018.00337