Ocean acidification: causes, impacts and solutions

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### Introduction and outline

**Burning of fossil fuels, cement manufacture and land use change**

- Relevant sections: [WGI 6.3.2] [WGI 2.2.1] [WGI 3.8.2, 30.2.2] [WGI 5.4.2.2, 5.4.4.2, 30.5.2, 30.5.3, 30.5.4, 30.5.6] [CC-CR, 5.4.2.2, 5.4.2.4, 30.6.2] [30.6.7]

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### Ocean warming and deoxygenation

**Driver**

- Burning of fossil fuels, cement manufacture and land use change

**Atmospheric change**

- Increase in atmospheric CO₂

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**Ocean Acidification**

- Increased CO₂, bicarbonate ions and acidity
- Decreased carbonate ions and pH

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**Changes to Organisms and Ecosystems**

- Reduced shell and skeleton production
- Changes in assemblages, food webs and ecosystems
- Biodiversity loss
- Changes in biogas production and feedback to climate

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**Socio-economic Impacts**

- Fisheries, aquaculture and food security
- Coastal protection
- Tourism
- Climate regulation
- Carbon storage

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**Policy Options for Action**

- UN Framework Convention on Climate Change: Conference of the Parties, IPCC, Conference on Sustainable Development (Rio+20)
- Convention on Biological Diversity
- Geoengineering
- Regional and local acts, laws and policies to reduce other stresses

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**High Certainty**

- **Gattuso et al. (2014; IPCC AR5 WGII)**
Burning of fossil fuels, cement manufacture and land use change

[WGI 6.3.2] [WGI 2.2.1] [WGI 3.8.2, 30.2.2]

Increase in atmospheric CO₂

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After Gattuso and Hansson (2011) and Gattuso et al. (2014; IPCC AR5 WGII)
Chemistry: very high confidence

<table>
<thead>
<tr>
<th>Driver</th>
<th>Atmospheric change</th>
<th>Ocean acidification</th>
</tr>
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| Burning of fossil fuels, cement manufacture, and land use change | Increase in atmospheric CO$_2$ | - Increased CO$_2$, bicarbonate ions, and acidity  
- Decreased carbonate ions and pH |

Relevant sections (WGI 6.3.2) (WGI 2.2.1) (WGI 3.8.2; WGII 5.3.3, 30.3.2)
Chemistry: very high confidence
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relevant sections
(WGI 6.3.2) (WGI 2.2.1) (WGI 3.8.2; WGII 5.3.3, 30.3.2)

$\text{CO}_2 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{CO}_3$

Acidity

- 1800
- 2000
- 2100

$+152$

$+34\%$
Chemistry: very high confidence

\[ CO_2 + H_2O \rightarrow H_2CO_3 \]

IPCC AR5 WG1 Report, Chap. 3 (2013)
Changes to organisms and ecosystems

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(WGII 5.4.2. 6.3.2, 30.5)
• Biological and ecological effects: high to low confidence
• Biogeochemistry: medium to low confidence
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(WGII 5.4.2. 6.3.2, 30.5)

- **Biological and ecological effects**: high to low confidence
- **Biogeochemistry**: medium to low confidence
- **Knowledge gaps**:
  - Multiple drivers
  - Evolutionary adaptation
  - Response of communities
  - Food web, up to predators
Society and the economy: medium to low confidence

Socioeconomic impacts

- Fisheries, aquaculture, and food security
- Coastal protection
- Tourism
- Climate regulation
- Carbon storage

(WGII 5.4.2.2, 5.4.2.4, 30.6.2, Box CC-CR)
1. INTRODUCTION

The term geoengineering as applied in its current context was introduced into the scientific literature by Victor Marchetti in the title of his classic paper describing deep-sea disposal of carbon dioxide (CO$_2$) (Marchetti 1977). This term has come to refer to large-scale efforts to diminish climate change resulting from greenhouse gases that have already been released to the atmosphere. Such efforts include both solar geoengineering (also known as solar radiation management, or SRM) and carbon dioxide removal (CDR) (R. Soc. 2009). SRM aims to diminish the amount of climate change produced by high greenhouse gas concentrations, whereas CDR involves removing CO$_2$ and other greenhouse gases from the atmosphere.

These geoengineering approaches may complement other strategies to diminish risks posed by climate change (Figure 1), including conservation (reducing demand for goods and services), efficiency (producing goods and services with few energy inputs), low- or zero-carbon emission energy technologies (producing that energy with sources that emit less CO$_2$), and adaptation (increasing resilience to effects of climate change that do occur). These various options are not mutually exclusive, although decisions must be made regarding how much effort should be put into each.

Most geoengineering approaches fall into one of two categories: carbon dioxide removal or solar geoengineering. These approaches can be viewed as part of a portfolio of strategies for diminishing climate risk and damage. Carbon dioxide removal attempts to break the link between CO$_2$ emissions and accumulation of CO$_2$ in the atmosphere. Solar geoengineering (also known as solar radiation management) attempts to break the link between accumulation of CO$_2$ in the atmosphere and the amount of climate change that can result.

Policy options for action

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Billé et al. (2013)
• Brings together end users, leading scientists and policy advisers
• Complements OA International Coordination Center (IAEA, Monaco)
• Advises on the types of products, content, style, and how to get them out with impact
• Multilingual guides produced
• Current activities: ‘Monaco Ocean Acidification Action Plan’, and ‘Ocean Acidification – getting ahead of the curve’, focussing on forecasting capabilities
Dissemination and outreach

Documents for policy makers – some written by EPOCA’s Reference User Group of stakeholders

World leading website and blog on ocean acidification

Dialogue with policy makers and media at climate change negotiations in Copenhagen, Cancun, Capetown and Warsaw

After C. Turley
Dissemination and outreach

Ocean Acidification Reference User Group

After C. Turley

Ocean Acidification November 2013

This document presents the highlights of the Frequently Asked Questions about Ocean Acidification (2010, 2012; ... organism at risk from ocean acidification. Photo by Nina Bednarsek (NOAA/PMEL).

Ocean Acidification

Messages for Rio+20

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Messages for Rio+20

Governments at Rio+20

The actions needed on ocean acidification by

Ocean Acidification Reference User Group

This briefing paper from the International

European Project on Ocean Acidification

the United Kingdom Ocean Acidification

the FAQ, which was produced by the Ocean Carbon and Biogeochemistry Project (OCB), inclusively and comprehensively addressed the question of ocean acidification. It was written by EPOCA’s group of about 60 scientists, science communicators, and science policy advisors asked to comment on details about ocean acidification.

Ocean acidification is the term used to describe the changes in ocean chemistry that are occurring as a result of anthropogenic addition of carbon dioxide (CO₂) to the atmosphere. Over the last two centuries, the concentration of atmospheric CO₂ has increased from about 280 parts per million (ppm) to about 400 ppm. The increase in atmospheric CO₂ has doubled the amount of acid in the ocean, which is causing ocean acidification.

Ocean acidification is most evident in the open ocean, where the pH of seawater is lowest and the concentration of carbonate ions is lowest. Carbonate ions are important to the growth and survival of marine organisms that make shells and skeletons. As the pH of seawater decreases, the concentration of carbonate ions decreases, making it more difficult for these organisms to build their shells and skeletons.

The effects of ocean acidification on marine organisms are expected to be severe, with some species already showing signs of stress. For example, Pteropods, also called sea butterflies, are one type of shelled organism at risk from ocean acidification. They are often considered a “canary in the coal mine” because they are sensitive to changes in ocean chemistry and are one of the first groups of marine organisms to show signs of stress.

The effects of ocean acidification are not limited to marine organisms. The ocean plays a critical role in regulating the Earth’s climate, and changes in ocean chemistry can have far-reaching implications for the planet.

The Intergovernmental Panel on Climate Change (IPCC) refers to a pH shift of 0.1 unit as the threshold above which significant biological changes will occur. This pH change is expected to occur by the end of this century, with a doubling of acidity by 2100, representing a doubling of acidity.

The ocean is not a static environment. It is constantly changing, and the changes in ocean chemistry that are occurring as a result of anthropogenic addition of carbon dioxide (CO₂) to the atmosphere are expected to continue for centuries to come. This increase in acidity of about 30% values of 7.8–7.9 are expected to create significant challenges for marine ecosystems and the people who depend on them.

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