GEOACTIVE 526

Sea-level change: impacts and strategies

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A case study about the impact of rising sea level

This case study explores the underlying causes of rising sea level across the world, and then focuses on the impact on one very vulnerable location – the Republic of the Maldives in the Indian Ocean. A rise in sea level is one of the most threatening features of climate change, and solutions will need to be found to protect low-lying communities around the world.

This case study covers:

- the causes of rising sea level
- the changing world climate
- the Maldives – environmental problems, and tackling these problems.

Key vocabulary

climate change, global warming, greenhouse gas, fossil fuel, acidity, ecosystem, carbon neutral

Learning outcome

At the end of this case study, you will have learned about rising sea level across the world, and the threat faced by one particularly vulnerable location – the Republic of the Maldives in the Indian Ocean. You will also have learned how that country plans to tackle the problems it faces.

Relevance to specifications

AQA A	Unit 2: Physical Geography, Section B, The Coastal Zone, page 15 http://filestore.aqa.org.uk/subjects/AQA-9030-W-SP-14.PDF
AQA B	Unit 1: Managing Places in the 21st Century, The Coastal Environment, Key Question: 'How can the management of coastal areas be increasingly sustainable?', page 10 http://filestore.aqa.org.uk/subjects/AQA-9035-W-SP-14.PDF
Edexcel A	Unit 1: Geographical Skills and Challenges, Section B, Challenges for the Planet, The Causes, Effects and Responses to Climate Change, page 15 http://www.edexcel.com/migrationdocuments/GCSE%20New%20GCSE/9781446911907_GCSE_Lin_Geog_A_Issue_5.pdf
Edexcel B	Unit 2: Dynamic Planet, Section B, Smallscale Dynamic Planet, Topic 5, Coastal Change and Conflict, page 16 http://www.edexcel.com/migrationdocuments/GCSE%20New%20GCSE/9781446911914_GCSE_Lin_Geog_B_Issue_5.pdf
OCR B	Unit B563: Key Geographical Themes, Unit 2, Theme 1, Rivers and Coasts, page 13 http://www.ocr.org.uk/Images/82581-specification.pdf
WJEC A	Unit 1: The Core, A, The Physical World, Theme 2, Climate Change, page 15 http://www.wjec.co.uk/uploads/publications/16128.pdf
WJEC B	Unit 2: Development and Problem Solving Geography, Theme 2, Physical Processes & Relationships Between People and Environments, Coastal Processes and Coastal Management, page 19 http://www.wjec.co.uk/uploads/publications/17213.pdf
CCEA	Unit 1: Understanding Our Natural World, Theme A, The Dynamic Landscape, pages 10–11; Theme B, Our Changing Weather and Climate, pages 12–13; a copy of the specification can be downloaded from: http://www.rewardinglearning.org.uk/microsites/geography/gcse/index.asp
Cambridge IGCSE	Theme 2: The Natural Environment, page 13 http://www.cie.org.uk/images/128378-2015-syllabus.pdf
Edexcel IGCSE	Section D, Global Issues, Topic 7, Fragile environments, see page 16 http://www.edexcel.com/migrationdocuments/IGCSE%20New%20IGCSE/IGCSE2009_Geography_(4GE0)_Specification.pdf

Sea-level change: impacts and strategies

Rising seas

A rise in sea level is one of the most threatening features of climate change. The world's oceans began to rise about 100 years ago, as global warming increased the average temperature of the Earth's atmosphere. Since then the mean sea level has gone up by 20 cm and could rise up to 1 metre by the end of this century (Figure 1).

This unit explores the underlying causes of rising sea level across the planet and then focuses on the impact on one very vulnerable location – the Republic of the Maldives in the Indian Ocean.

There are three main causes of rising sea level:

1 **Glaciers melt and their water runs into the oceans** In each of the 20 years to 2010 it is estimated that 275 billion tonnes of ice was lost from the world's glaciers. Scientists calculate that 35–85% of remaining glacier volume will vanish by 2100 if greenhouse gas emissions are not curbed.

2 **Large ice caps melt or break up into the oceans** The world's two biggest ice caps are in Antarctica and Greenland. Their rate of melting went up by five times in the first decade of the 21st century compared with the 1990s. Sea ice in the Arctic Ocean has been melting by more than 10% a decade since 1980.

3 **Water expands as it heats** Between 1971 and 2010, 90% of the extra energy put into the climate system by global warming was absorbed by the oceans.

In the past, expanding oceans were the most important factor in sea-level rise, but now melting ice has become the main reason. An additional problem is that oceans absorb carbon dioxide, increasing their acidity. This acidity harms the types of marine life that form shells, and also attacks coral reefs.

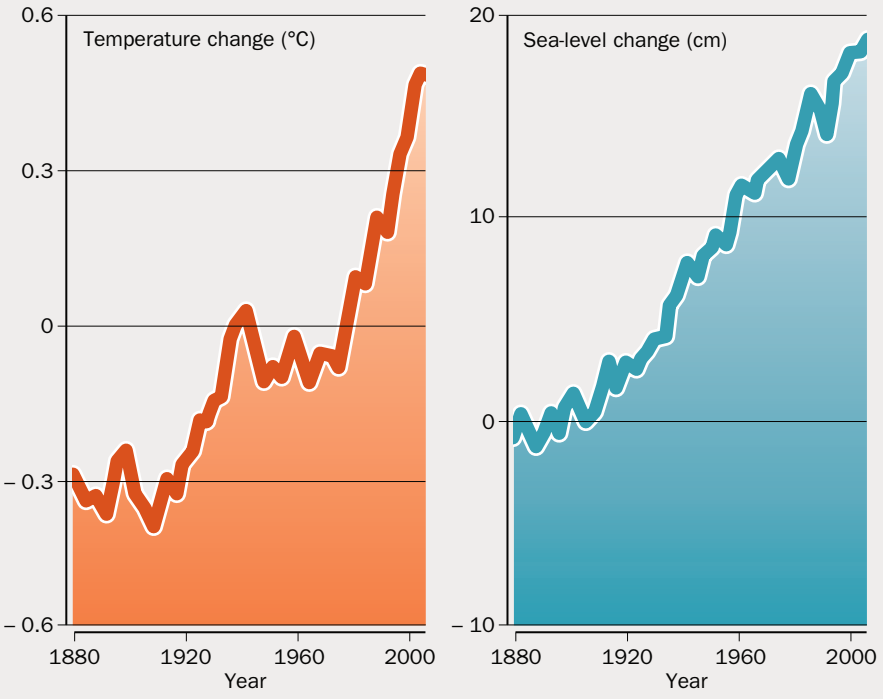

Figure 1 Global temperature and sea-level changes, 1880–2001

Source: PSMSA; NASA

The changing world climate

In September 2013 the Intergovernmental Panel on Climate Change (IPCC) published its latest report on global climate. Drawing on the work of more than 800 scientists from around the world, its predictions outlined a disturbing picture of future climate trends. The main conclusions of the report were:

- Climate change has affected every region of the globe, on land and at sea.
- Global warming is the result of human activities that release greenhouse gases into the atmosphere. There has been a 40% increase in carbon dioxide in the atmosphere over the past 250 years, chiefly due to the burning of fossil fuels since the Industrial Revolution in the 18th and 19th centuries.
- The global temperature increased by 0.9°C in the 20th century. By 2100 it is expected to be at least 2°C higher than it is now if carbon emissions continue to rise. This is likely to have dangerous consequences, including droughts, famines, floods and storms (Figure 2).

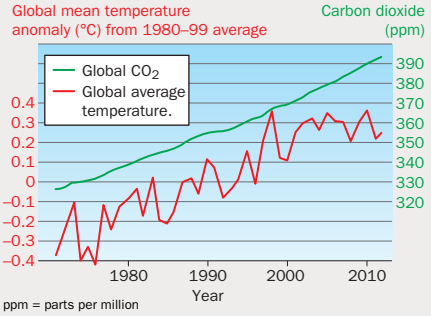

Figure 2 Global temperatures and atmospheric carbon dioxide, 1971–2012

Source: Scripps Institution of Oceanography

- Sea-level rise and more powerful tropical storms are putting small island states, coastal lowlands and cities at risk, especially in Asia. Around 1 billion people living in such areas face the hazards of flooding, storm surges and violent cyclones.

Case Study: The Maldives

Geographical background

The Maldives is the lowest-lying country in the world. As such, it is also most at risk from the effects of rising sea level. The geography of the Maldives has made it an extreme test case for climate change action:

- The 1000 km long island chain in the Indian Ocean has an average height of 1.5 metres. Its highest point is only 2.4 metres above sea level.
- The archipelago consists of 1200 islands, grouped into 26 coral atolls. Its total landmass represents just one-fifth the area of Greater London (Figure 3).
- The islands lie on top of tall coral columns which in turn are built on ancient underwater mountains.
- Globally coral reefs are the most endangered ecosystem.
- The population of almost 400 000 inhabits 200 islands but over a quarter of Maldivians live in the country's capital, Malé (Figure 4).
- Malé (pronounced *Ma-lé*) is the most densely populated city in the world, with 110 000 people occupying 2 km² of land.

The mainstay of the Maldives' economy is international tourism, based on its reputation as a tropical ocean paradise. Over the past 40 years more than 100 luxury island resorts have been developed by multinational hotel firms, and another 50 are planned (see Figure 5). In 2013 the annual number of tourist arrivals topped 1 million for the first time. Import duties and tourism-related taxes account for 90% of government income and 60% of the country's foreign exchange earnings. Nevertheless, the country is heavily in debt, spending 25% of its GDP on diesel fuel which provides its entire energy requirements.

The only other significant activity is fishing: tuna are caught using pole and line, the most sustainable method available, but large reef-dwelling species are being overfished, threatening the ecosystem.

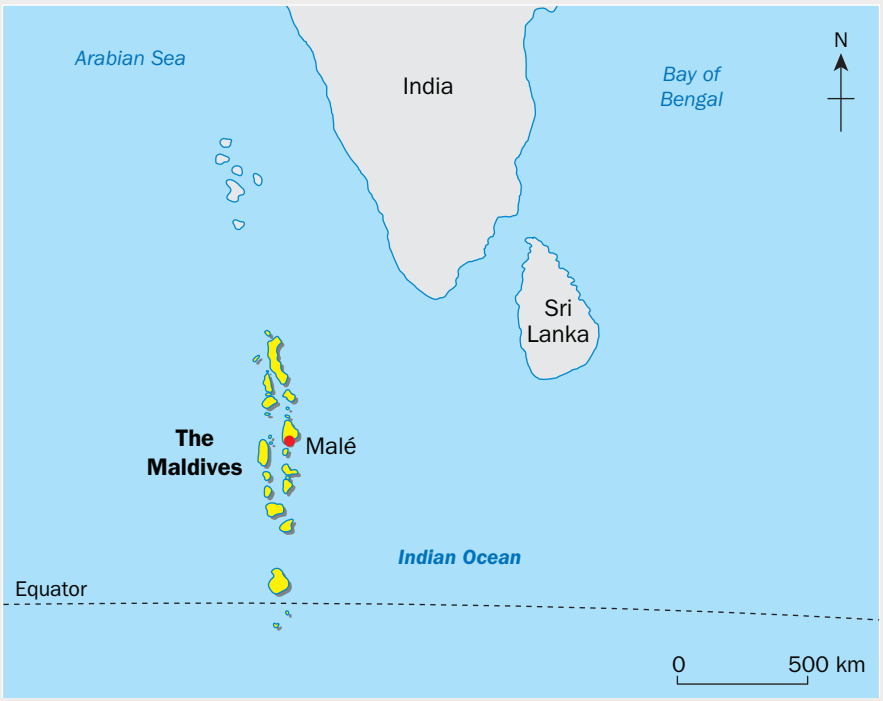

Figure 3 Location of the Maldives

Figure 4 Malé

Source: Photo by Mike Morrish

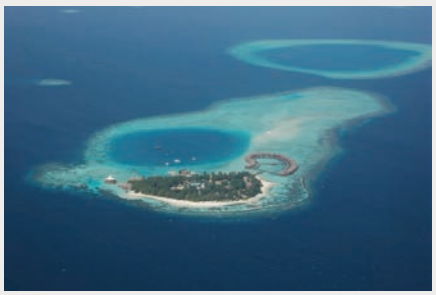

Figure 5 A resort island
Source: Photo by Mike Morrish

On average the Maldives is the richest country in South Asia, with a mean income of £3000 a year. However, wealth is unequally spread and almost half of Maldivians earn less than $1 a day. One in five people are unemployed. Travel is expensive and many people spend their lives in a small island locality, rarely venturing further. Tourists see little of traditional Maldivian society, going straight from the airport to their resort by boat or seaplane and then staying there.

Environmental problems

A number of environmental problems are increasingly affecting the Maldives as a result of global warming and rising sea level:

1 **Sea-level rise** The 2013 IPCC report predicted a future rise in sea level of up to 1 metre by 2100. This could make the Maldives uninhabitable and force its population to migrate elsewhere. In 1987, Malé and other occupied islands were inundated by unusually high tides. Worse was to come in December 2004, when the Asian tsunami brought more devastation. Although the wave was only 1 metre high, it killed 82 people and made 12 000 homeless. Damage – of which over a quarter was inflicted on beach resorts – totalled £250 million.

2 **Coral reef destruction** Both rising sea temperatures and increasing acidity attack the coloured algae that live in and feed the corals. This leads to coral bleaching and crumbling, degrading the reefs that absorb wave energy and protect the enclosed islands and lagoons.

3 **Wave erosion** Although this is a natural process that occurs in 80–90% of islands in the Maldives, it has been made more powerful by rising seas, stronger waves and stormier weather.

4 **Extreme and erratic weather** Climate change brings more turbulent and unpredictable weather patterns. A decade ago the Maldives only experienced a severe event once every year or two but now they happen two or three times each year. Violent thunderstorms can cause flash floods.

5 **Fresh water shortages** The dry season in the Maldives is getting longer and more intense, creating problems with drinking water supplies. More than a quarter of the populated islands now require water shipments when supplies run low. In addition, bigger ocean swells are driving waves across some islands, contaminating the fresh groundwater with salt.

6 **Disease** Hotter, wetter conditions during the rainy season encourage the spread of mosquitoes which breed in standing water and transmit dengue fever.

7 **Dwindling fish stocks** Between 2006 and 2011, tuna catches in the Maldives fell by 40%. This is thought to be linked to fish moving to cooler water, or a lack of food, due to changing weather conditions.

Strategies to tackle impacts of climate change

In November 2008, Mohamed Nasheed became the first democratically elected president of the Maldives. The 41-year-old human rights activist immediately set about publicising the environmental crisis facing his country. As a prominent leader of AOSIS – the Alliance of Small Island States – he became a globally recognised spokesperson for low-lying countries in imminent danger from rising sea level. Nasheed launched a series of attention-grabbing initiatives that challenged politicians throughout the world.

- **A new homeland for the Maldives?** As soon as he took office, President Nasheed announced his intention to buy land abroad as a new homeland for Maldivians if their islands were drowned. He would create a 'sovereign wealth fund' from tourist revenues and use this to approach potential host nations like India or Sri Lanka, which have similar cultures. His argument was that if the Maldives became uninhabitable, his people had a right to stay together and preserve their culture. In any case, climate change was not their fault and had been caused by rich nations.
- **Maldives – the first 'carbon-neutral' country?** In March 2009 Nasheed unveiled a plan to switch the Maldives within a decade from its dependence on oil to 100% renewable energy. Therefore it would no longer be a net contributor to global carbon emissions.
- **Solar power** In September 2009 the Japanese government gave $10 million to equip schools and government buildings in Malé with solar panels.

- **The underwater cabinet meeting** In October 2009, Nasheed held a cabinet meeting under the sea off Girifushi Island, to highlight the plight of the Maldives. All his ministers sat at tables wearing wetsuits and scuba gear.
- **Wind-farm plan** In November 2009 plans were outlined for a 30-turbine wind farm close to Malé. This would provide 40% of the country's energy – the highest proportion of renewable power in the world. It would produce 75 MW at full capacity, enough for the capital, the airport and nearby resort islands. Surplus electricity would run desalination plants for the production of bottled water.
- **The 2020 carbon neutral plan** In September 2011 Nasheed's government released the Maldives Renewable Energy Investment Framework, aiming for an 80–90% reduction in electricity emissions by 2020. It also set a target of delivering 60% of electricity from solar power over the same timescale, with a biomass power station on larger islands to supplement supplies. However, the plan did not cover emissions from cars, boats and cooking stoves; nor did it include air travel.

In February 2012 Mohamed Nasheed was forced to resign at gunpoint when elements of the police and military carried out a coup. Nasheed ran for the Maldivian presidency again in the elections of September 2013 but was defeated by Abdulla Yameen.

The new island of Hulhumalé

Although the political removal of President Nasheed sidelined many of his innovative plans, one major project has gone ahead. A completely new island has been created by dredging sand from nearby lagoons. It is called Hulhumalé, meaning 'New Malé'. When the second phase of development is finished, the 2 metre high island will cover 420 hectares and house 160 000 people, mainly in large blocks of social housing.

Activities

1 Match the following terms to the definitions given below:

a climate change
b global warming
c greenhouse gas
d fossil fuel
e greenhouse effect

1 The gradual rise in the Earth's mean temperature
2 Naturally occurring energy source formed from the remains of organic matter
3 The warming of a planet's atmosphere due to the trapping of outgoing heat
4 Changes to the Earth's climatic systems, linked to atmospheric warming
5 Any atmospheric gas that traps heat, for example water vapour, carbon dioxide, methane

2 Look at Figure 2. Describe the patterns of change in global temperatures and carbon dioxide between 1971 and 2012. What is the difference in the rate of temperature change before and after 2000?

3 Figure 6 lists nine ways in which the impact of climate change could be slowed down by reducing carbon emissions. Each method would also have economic benefits in terms of reduced spending. Choose **three** measures and for each explain how it would benefit

a the economy and
b the climate.

4 Copy this paragraph and fill in the gaps using the list of words provided underneath. You can refer to an atlas and the information in this unit to help you.

The Maldives is a chain of _____ islands in the _____ Ocean. This 1000 km long _____ lies mainly north of the _____ , close to the _____ tip of India and the _____ of Sri Lanka. The country consists of 26 coral _____ , which developed on a line of _____ mountains. Being so low-lying, the _____ are at risk from _____ sea level and their _____ reefs are under attack from _____ of the oceans.

atolls	tropical	southern	rising
Indian	archipelago	equator	underwater
acidification	island	coral	Maldives

Measure	Economic benefit (/12)	Climate benefit (/6)
Residential home energy efficiency	12	5
Public building energy efficiency	12	5
Boiler replacement programme	12	5
Light and appliance replacement	12	5
Fuel-efficient new cars	10	6
Renewable heat generation	10	5
Renewable energy development	9	6
Vehicle tyre pressure checks	11	4
Reducing deforestation	10	5

Figure 6 Measures to reduce carbon emissions

Source: 'An outline of the case for a "green" stimulus', by A. Bowen, S. Frankhauser, N. Stern and D. Zenghelis

5 Go to the official Maldives tourism website at:

www.visitmaldives.com

a Identify **ten** features of its island resorts and their natural environment that make the Maldives a highly attractive holiday destination.

b Is there any evidence on the website of the threat posed to the tourist industry by rising sea level?

6 Study Figure 7. This picture was taken on an island resort in the Maldives in 2012.

a How can you tell this is a holiday resort?

b What is the evidence of coastal erosion in the photograph?

c How are the resort owners attempting to improve the beach?

d Who is carrying out this work?

e How effective do you think these measures will be?

7 Refer to the newspaper article about climate change and Pacific small island 'microstates' that can be found at:

www.theguardian.com/environment/2013/sep/01/pacific-islands-climate-change

As you read through it, make a note of all the similarities between the islands described in the article and what you have learnt about the Maldives. How many common features can you identify?

Figure 7 Beach replenishment

Source: Photo by Mike Morrish

Checkpoint

- Climate change is causing rising sea level globally.
- The low-lying Maldives Islands are particularly vulnerable to a rise in sea level.
- There are already environmental problems – and Maldivians may need to find a new homeland in future.

Glossary task

Write glossary definitions for these terms:

Acidity
Carbon neutral
Climate change
Ecosystem
Fossil fuel
Global warming
Greenhouse gas

Remember this case study

To help you remember this case study, make notes under the following headings:

Effects of climate change

Problems faced by the Maldives

Tackling the problems now

Plans for the future

Try to make your notes fit a single sheet of A4.