



## Climate change

Only recently has it been possible directly to measure temperature, rainfall and the other weather variables that make up our climate. However, using indirect measures, such as historical records, tree-ring data (going back about 10,000 years), ice-core samples (going back to 100,000 years ago), sea-sediment samples (some going back millions of years) and rock samples (laid down as sea sediment hundreds of million years ago), scientists have been able to show that the earth's climate has changed repeatedly over geological time. Generally, long periods of relative stability have been interspersed with periods of rapid change.<sup>1,2</sup>

Ultimately, the temperature of the planet, and so its climate, is controlled by how much solar radiation — mainly short-wave visible light and ultraviolet (UV) light — we receive from the sun and how much is reflected back into space. It is postulated, for example, that the last ice ages were precipitated by a slight wobble in the earth's axis, increasing our distance from the sun and so reducing the amount of energy we received. However, the amount of radiation that penetrates the atmosphere to reach the surface of the planet is also important. Particulate matter in the atmosphere, such as clouds, soot, dust and aerosols, scatter and reflect the sun's energy. Large volcanic eruptions can reduce direct sunlight by 5–10 per cent, leading to global cooling which may last a number of years. The eruption of Mount Pinatubo in the Philippines in 1991 caused a global temperature drop of up to 0.3°C.

Overall, about 20 per cent of the energy that enters our atmosphere from the sun is reflected back into space. Of the rest, about 10 per cent is reflected back by the earth's surface. Clouds and gases in the atmosphere, and soil, water and vegetation, absorb the rest.<sup>3,4</sup>

### The greenhouse effect

The greenhouse effect has made life on earth possible for us, keeping the earth about 33°C warmer than it would otherwise be, at an average of +15°C rather than -18°C. The problem now facing us is the extent to which human activities are increasing this natural effect to the point that it leads to levels of climate change that threaten our planet's environment.

Solar energy falling on the earth warms its surface, and some is re-radiated back in the form of invisible long-wave infrared radiation (IR) — heat.

“Greenhouse gases” in the atmosphere (which have allowed most solar, short-wave radiation to pass) trap much of the long-wave radiation, causing the atmosphere to warm, just as in a greenhouse.

### Greenhouse gases

Table 1 on the next page shows the average composition of dry gases in the atmosphere at low altitude.

- Water vapour is additional to these figures. It is responsible for up to 70 per cent of the natural greenhouse effect but, because it forms clouds

and rain, its concentration changes rapidly and it provides a very important feedback system, helping to reduce temperature.

- Carbon dioxide (CO<sub>2</sub>) is the principal contributor to the total greenhouse effect after water vapour. It is released into the atmosphere in large quantities, in particular by the combustion of fossil fuels.
- Methane is a much more potent greenhouse gas than CO<sub>2</sub>, molecule for molecule, but is less influential because it is much less abundant.
- Nitrous oxide is another potent greenhouse gas, but again is present only in small quantities.

Basic physics tells us that an increase in any of these gases is likely to cause more heat to be retained by the atmosphere, and a corresponding increase in global temperature.

**Table 1:** Pre-2010 average composition of gases in the dry atmosphere (below 25 km altitude)

Gas	Percent volume
Nitrogen	78.08%
Oxygen	20.95%
Argon	0.93%
Carbon dioxide*	~0.038%
Neon	0.0018%
Helium	0.0005%
Methane	~0.00018%
Hydrogen	0.00005%
Nitrous oxide	~0.00003%
Ozone	~0.000004%

\*Note CO<sub>2</sub> concentration had reached more than 0.04% by March 2016

Over the last 150 years, the level of CO<sub>2</sub> in the atmosphere has increased from about 280 parts per million, to 380 parts per million five years ago and an average of 404.8 parts per million in March 2016,<sup>5</sup> due, in part, to deforestation, changes in land use and the burning of fossil fuels that has been necessary to support increased industrialization and an exploding population. For the same reasons, levels of most of the other greenhouse gases have also increased, and new ones — for instance the chlorofluorocarbons (CFCs) — have been added to the mix.<sup>6,7</sup>

As long ago as 1896, the Swedish scientist Svante Arrhenius<sup>8</sup> suggested that carbon dioxide emissions from burning fossil fuels would enhance greenhouse gases, and so lead to global warming. Since the advent of computers, climatologists have been investigating this, using increasingly sophisticated models of the world’s climate. Because the climate is an immensely complex system, the results are varied, depending on the parameters used, but they suggest that global warming will occur, and they point to some of the effects this might have on the planet.

Although a very few scientists still argue that any changes we see are “natural” and that we have no effect on the climate, the vast majority now believe that our activities are a major factor causing the atmosphere to warm. In recent years many of the predicted effects have become only too apparent, and they will continue to become worse — much worse, if we continue to increase the levels of greenhouse gases in the atmosphere.

## Effects of climate change

### Global warming

The average global temperature has risen by about 0.7°C in the last 100 years. If CO<sub>2</sub> levels are stabilised at 550 parts per million by the end of this century — double the pre-industrial levels — a further increase of 2°C to 4.5°C is expected, with a best estimate of about 3°C.<sup>9</sup> If CO<sub>2</sub> levels increase more, larger temperature rises are likely.

### Sea level rise

Sea levels have risen by an average of about 1.75mm per year over the last 100 years, with satellite image measurements suggesting that this has now increased to about 3.1mm per year.<sup>10</sup> Projections suggest that the rate of sea level rise is likely to increase during the 21<sup>st</sup> century, but the likely size of the increase is more uncertain. The rise is caused by the thermal expansion of water as it warms, and by the melting of glaciers and ice sheets. Because the behaviour and effect of the latter on sea level is not well understood, the rise could, potentially, be much more.

For the millions of people who live only a few metres above sea level, this is a potential disaster. Many will lose homes and land to the sea, and many more are likely to be periodically affected by storm surge. They, too, may need to relocate; repeated immersion in salt water destroys homes, lives and farmland. Although rich countries will be affected — New York, New Orleans, Tokyo and the Netherlands are among the places most at risk — sea level rise is likely to have a disproportionately large effect on some of the poorest and most populated countries in the world. Bangladesh, for example, is predicted to lose 15 per cent of its land, displacing millions of people and severely reducing the crucial rice crop for many others.<sup>11</sup>

### Glacier melt

Glaciers worldwide act as natural reservoirs, accumulating snow in winter and slowly releasing it as water during the rest of the year. As glaciers retreat, they are less able to do this, leaving many of the world's most vulnerable people with reduced water supplies. Studies conclude that many Peruvian glaciers will disappear within 20 years, threatening the water supplies of 77 million people, and half the electricity generated in Peru, Bolivia and Ecuador.<sup>12,13</sup>

### Extreme weather

Extreme weather events are likely to become more common, with an increase in both tropical storms and droughts. Rainfall is predicted to increase both in the tropics and at high latitudes, although in many places

it may rain less often but more heavily at any one time, leading to flooding.



There is likely to be a decrease in rainfall in the already-dry areas of the subtropics. A severe drought in the Eastern Sahel in 2010 caused massive loss of farmed animals and food crops, and brought hunger to at least 10 million people. As populations continue to rise, and as extreme weather events become more frequent, we are likely to see more such disasters.<sup>14,15</sup>

### Temperature rise

The temperature rise will, of itself, cause problems.

At present, cold winters help to control many agricultural pests. However, the general warming of the climate will result in less cold winters, allowing these pests to multiply and threaten the crops on which we depend.

Many diseases are found only in tropical areas; as these tropical areas extend, so will the diseases and the organisms that transmit them — West Nile virus has recently been found as far north as Canada. Plants and animals are temperature-sensitive too. Research suggests that high night-time temperatures cause a significant reduction in the productivity of rice — the staple diet of more than half the world's population — and many farmed animals in the tropics are already living at temperatures close to the maximum they can tolerate.

Changes in rainfall and temperature patterns further suggest that the fertile areas of the globe may change: areas that are presently too cold for agriculture may become warmer, and those that are

too dry may become wetter so that farming becomes possible. In other areas, farms may be lost. Where agriculture is possible, farmers will have to use new varieties and learn new practices. However, most subsistence farmers do not have the capital to buy new seed, or the time to learn new methods.

Rising sea level and changes in land fertility will mean that millions of people will have to relocate; but in an already-crowded world, it is difficult to see where they can go. India is already extremely worried by the possibility of an influx of millions of Bangladeshi refugees. There are real fears that wars and conflicts will increase as “climate change refugees” attempt to migrate to areas that are already overpopulated beyond levels of sustainability.<sup>16</sup>

## Carbon dioxide

An increase in carbon dioxide in the atmosphere boosts plant growth, potentially increasing crop yields, but it is thought that this will be offset by the many other factors reducing yields. Increased CO<sub>2</sub> is also being absorbed by the oceans, causing the acidity of the sea to rise (i.e. the pH to fall). It has been shown that even small decreases in pH affect the ability of many sea creatures to survive; the calcium carbonate, of which their skeletons and shells are made, starts to dissolve. Corals, sea urchins and sea snails fare badly, as do many plankton (very small sea creatures). Plankton “fix” hundreds of thousands of tons of CO<sub>2</sub> annually; it is locked into their skeletons, and falls to the ocean floor when they die. Without the present numbers of plankton, levels of CO<sub>2</sub> in the atmosphere will rise even faster than they are doing at present.<sup>17</sup>

Coral reefs occur in the waters of more than 100, mainly developing, countries worldwide; an estimated 500 million people rely at least partly on these reefs for their food and livelihoods.

In summary, climate change is fast altering every environment on earth, and resulting in losses of biodiversity and changes in food productivity. Many of the areas of the world most badly affected, both now and in the foreseeable future, are in developing

countries. These countries are already suffering from massive poverty and the pressures of ever-expanding human populations. Climate change can only make things worse — and these peoples are the least equipped and least able to cope with its damaging consequences.

## Methodology and agreements

### *Contraction and convergence (C&C)*

C&C is a global framework devised by the Global Commons Institute with the aim of reducing greenhouse gas emissions and thereby preventing catastrophic climate change.<sup>18</sup> It is proposed as the basis of an equitable international strategy, whereby rich countries **restrain their future consumption** rather than continuing to enjoy living standards in excess of what the planet can support for everyone.

### *UNFCCC COP21 Paris agreement 2015*

The United Nations Framework Convention on Climate Change (UNFCCC) reached an international agreement to respond to the threat of climate change at the Paris 2015 Conference of Parties (COP21).<sup>19</sup> The aim of the agreement, subsequently signed on 22<sup>nd</sup> April 2016<sup>20</sup>, is to keep global temperature rise this century below 2°C above pre-industrial levels; there is a further aspiration of limiting this to 1.5°C.<sup>21</sup>

The Parties to the agreement are required to prepare nationally-determined contributions to mitigation of climate change, though these were not quantified at the time.

The agreement includes an obligation for developed countries to help developing countries, both to adapt to climate change and to mitigate their own contribution. However, despite referring to the principle of equity several times, the text of the agreement<sup>22</sup> does not provide a quantitative framework for achieving this (for example Contraction & Convergence), and therefore suggests the climate change targets can be achieved both equitably and without constraining living standards of those in high-consuming countries; this is something for which

there is scant evidence, and which many environmentalists believe to be unrealistic.

Neither does the agreement appear to have paid serious attention to addressing population size as one of the principal drivers of climate change. The UN publication *World Population Prospects 2015* gives the high population projection for 2050 as 24 per cent larger than the low projection, and for 2100 the high

projection is more than double the low one.<sup>23</sup> Such a large range of potential population size implies an enormous difference in the difficulty of limiting global temperature rise, suggesting that ethically-acceptable means of constraining the outcome to the lower end of the projected range is a top priority for the effort to avoid dangerous levels of climate change.

## References

All Internet references accessed April 2016.

- <sup>1</sup> <http://arstechnica.com/science/news/2006/11/6027.ars>
- <sup>2</sup> [http://www.nature.nps.gov/geology/nationalfossilday/climate\\_change\\_earth\\_history.cfm](http://www.nature.nps.gov/geology/nationalfossilday/climate_change_earth_history.cfm)
- <sup>3</sup> <http://www.physicalgeography.net/fundamentals/7y.html>
- <sup>4</sup> <http://webarchive.nationalarchives.gov.uk/20121212135622/http://www.bis.gov.uk/go-science/climatescience/greenhouse-effect>
- <sup>5</sup> <http://www.esrl.noaa.gov/gmd/ccgg/trends/>
- <sup>6</sup> <http://www.bis.gov.uk/go-science/climatescience/greenhouse-effect> (go to archive)
- <sup>7</sup> <http://www.esrl.noaa.gov/gmd/ccgg/trends/>
- <sup>8</sup> [http://www.rsc.org/images/Arrhenius1896\\_tcm18-173546.pdf](http://www.rsc.org/images/Arrhenius1896_tcm18-173546.pdf)
- <sup>9</sup> <http://ghgonline.org/predictions.htm>
- <sup>10</sup> <http://www.climate.org/topics/sea-level/index.html>
- <sup>11</sup> <http://www.worldbank.org/en/news/press-release/2013/06/19/warming-climate-to-hit-bangladesh-hard-with-sea-level-rise-more-floods-and-cyclones-world-bank-report-says>
- <sup>12</sup> [http://meteora.ucsd.edu/cap/pdf/barnett\\_warmsnow.pdf](http://meteora.ucsd.edu/cap/pdf/barnett_warmsnow.pdf)
- <sup>13</sup> <http://www.guardian.co.uk/environment/2006/aug/29/glaciers.climatechange>
- <sup>14</sup> [https://www.foe.co.uk/sites/default/files/downloads/extreme\\_weather\\_cc.pdf](https://www.foe.co.uk/sites/default/files/downloads/extreme_weather_cc.pdf)  
<http://www.theguardian.com/world/2010/aug/09/floods-mudslides-drought-extreme-weather>
- <sup>15</sup> <http://www.theguardian.com/environment/2010/jun/03/drought-hunger-west-africa>
- <sup>16</sup> <http://www.fmreview.org/crisis/bose.html>
- <sup>17</sup> <http://www.scientificamerican.com/article.cfm?id=rising-acidity-in-the-ocean>
- <sup>18</sup> <http://www.gci.org.uk/index.html>
- <sup>19</sup> <http://www.cop21.gouv.fr/en>
- <sup>20</sup> <http://www.theguardian.com/environment/2016/apr/22/un-climate-change-signing-ceremony>
- <sup>21</sup> <http://bigpicture.unfccc.int/#content-the-paris-agreemen>
- <sup>22</sup> <https://unfccc.int/resource/docs/2015/cop21/eng/l09.pdf>
- <sup>23</sup> [http://esa.un.org/unpd/wpp/Publications/Files/WPP2015\\_Volume-I\\_Comprehensive-Tables.pdf](http://esa.un.org/unpd/wpp/Publications/Files/WPP2015_Volume-I_Comprehensive-Tables.pdf)