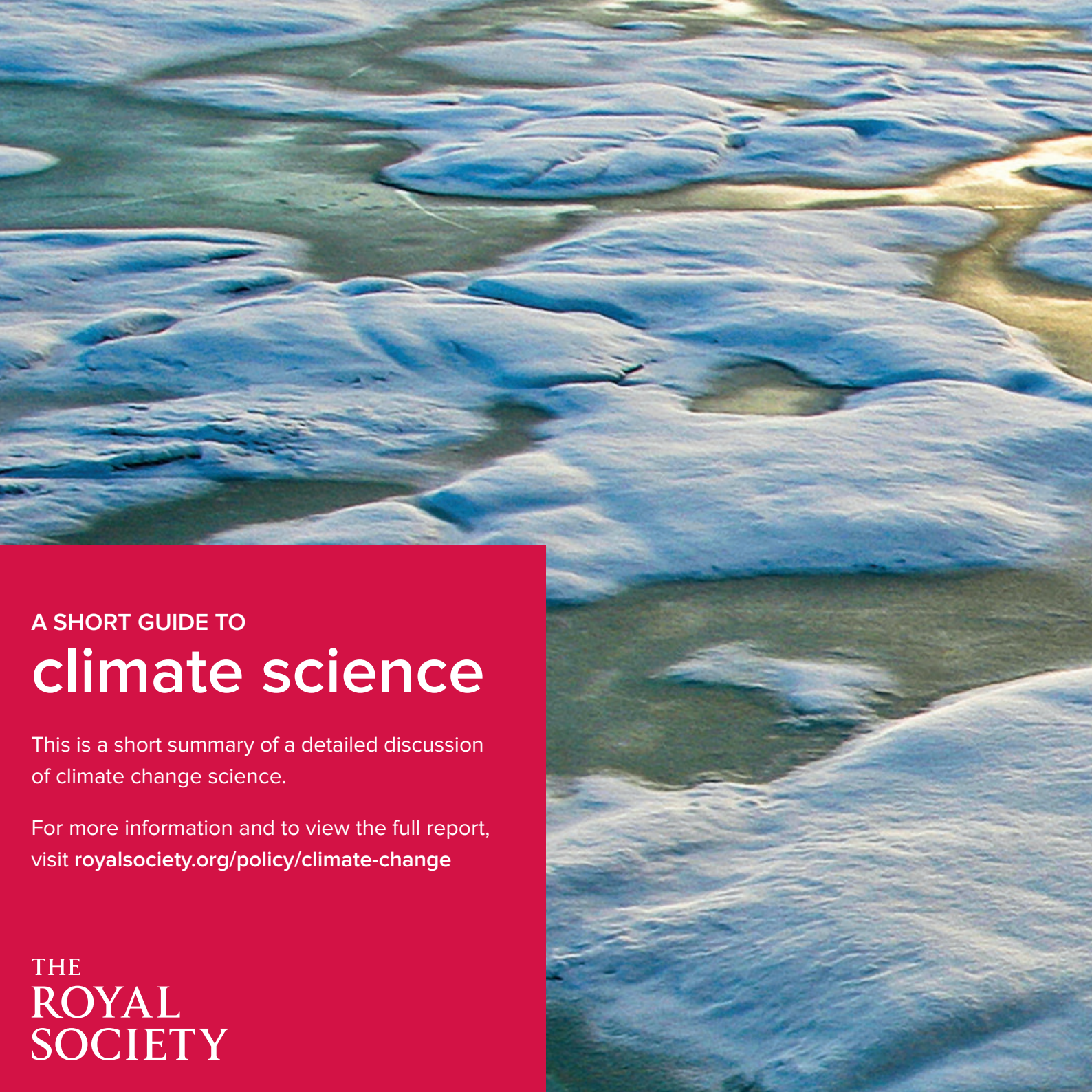

A SHORT GUIDE TO

# climate science

This is a short summary of a detailed discussion of climate change science.

For more information and to view the full report, visit **royalsociety.org/policy/climate-change**

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## 1. Is the climate warming?

Yes. Earth's average surface air temperature has increased by about 0.8 °C (1.4 °F) since 1900, with much of this increase taking place since the mid-1970s. A wide range of other observations such as sea-level rise, reduced Arctic sea ice extent and increased ocean heat content provide incontrovertible evidence of a warming Earth.

## 2. How do scientists know that recent climate change is largely caused by human activities?

Human activity leads to emissions of greenhouse gases (causing warming), and of other pollutants that produce small particles in the atmosphere (which can have both cooling and warming effects). The dominant influence of human activities on recent climate change is clear from an understanding of the basic physics of the greenhouse effect and from comparing the detailed patterns of recent climate change with those expected from different human and natural influences. Only when human influences on the composition of the atmosphere are incorporated can models reproduce observed changes in climate.

## 3. $CO_2$ is already in the atmosphere naturally, so why are emissions from human activity significant?

Human activities have significantly disturbed the natural carbon cycle by extracting long-buried fossil fuels and burning them for energy, thus releasing $CO_2$ to the atmosphere. The concentration of $CO_2$ has increased by 40% since the Industrial Revolution.

## 4. What role has the Sun played in climate change in recent decades?

The Sun has not played a major role in recent climate change. The Sun provides the primary source of energy driving Earth's climate system and variations in the energy emitted by the Sun affect Earth's climate. However, satellite measurements since the late 1970s show no overall increase in the energy emitted by the Sun, while the climate system has warmed.

## 5. What do changes in the vertical structure of atmospheric temperature – from the surface up to the stratosphere – tell us about the causes of recent climate change?

The observed warming in the lower atmosphere and cooling higher up in the stratosphere is the result expected from increases in $CO_2$ and decreases in stratospheric ozone. Natural factors alone cannot explain the observed changes.

## 6. Climate is always changing. Why is climate change of concern now?

All major climate changes, including natural ones, are disruptive. Past climate changes led to extinction of many species, population migrations, and pronounced changes in the land surface and in ocean circulation. The speed of the current climate change makes it more difficult for human societies and the natural world to adapt.

## 7. Is the current level of atmospheric $CO_2$ concentration unprecedented in Earth's history?

The present level of atmospheric $CO_2$ concentration is almost certainly unprecedented in the past million years, during which time modern humans evolved and societies developed. The atmospheric $CO_2$ concentration was however higher many millions of years ago, at which time temperatures and sea levels were also higher than they are today.

## 8. Is there a point at which adding more $CO_2$ will not cause further warming?

No. Adding more $CO_2$ to the atmosphere will cause surface temperatures to continue to increase. The addition of extra $CO_2$ becomes progressively less effective at trapping Earth's energy, but surface temperature will still rise.

## 9. Does the rate of warming vary from one decade to another?

Yes. The observed warming rate has varied from year to year, decade to decade, and place to place. These shorter-term variations are mostly due to natural causes, and do not contradict our fundamental understanding that the long-term warming trend since the mid-20th century is primarily due to human-induced changes in the atmospheric levels of $CO_2$ and other greenhouse gases.

## 10. Does the recent slowdown of warming mean that climate change is no longer happening?

No. Since the very warm surface temperatures of 1998 which followed the strong 1997-98 El Niño, the increase in average surface temperature has slowed relative to the previous decade of rapid temperature increases, with more of the excess heat being stored in the oceans. Despite the slower rate of warming, the surface temperatures in the 2000s were on average warmer than the 1990s.

## 11. If the world is warming, why are some winters and summers still very cold?

Global warming is a long-term trend, but that does not mean that every year will be warmer than the previous one. Day to day and year to year changes in weather patterns will continue to produce some unusually cold days and nights, and winters and summers, even as the climate warms.

## 12. Why is Arctic sea ice reducing while Antarctic sea ice is not?

Sea ice extent is affected by winds and ocean currents as well as temperature. Sea ice in the partly-enclosed Arctic Ocean seems to be responding directly to warming, while changes in winds and in the ocean seem to be dominating the patterns of sea ice change in the Southern Ocean around Antarctica.

## 13. How does climate change affect the strength and frequency of floods, droughts, hurricanes and tornadoes?

Earth's lower atmosphere is becoming warmer and moister as a result of human-emitted greenhouse gases. This means that more water is likely to be drawn into major rain storms, which could lead to more flooding events. There is considerable uncertainty over changes in hurricanes and tornadoes, but the extra energy available may make the strongest hurricanes stronger. Dry areas of the subtropics are expected to become drier in the future.

## 14. How fast is sea level rising?

Best estimates of the global-average rise over the last two decades suggest 3.2 mm per year (0.12 inches per year). The overall observed rise since 1901 is about 20 cm (8 inches). If $CO_2$ and other greenhouse gases continue to increase on their current trajectories, it is projected that sea level may rise by a further 0.5 to 1 m (1.5 to 3 feet) by 2100.

## 15. What is ocean acidification and why does it matter?

About a quarter of the emissions of carbon dioxide from human activities are soaked up by oceans each year. The extra $CO_2$ causes the chemical balance of seawater to shift to a more acidic state (lower pH) and some corals and shellfish have shells composed of calcium carbonate which dissolves more readily in acid. Acidification is likely to shift the competitive advantage among species, with as-yet-to-be-determined impacts on marine ecosystems and the food web.

## 16. How confident are scientists that Earth will warm further over the coming century?

Very confident. If emissions continue on their present trajectory, then warming of 2.6 to 4.8 °C (4.7 to 8.6 °F), in addition to that which has already occurred, would be expected by the end of the 21st century. The range of values accounts for the fact that there are open questions as to how exactly some natural processes such as cloud formation amplify or reduce the direct warming effect of increasing levels of $CO_2$.

## 17. Are climate changes of a few degrees a cause for concern?

Yes. Even though an increase of a few degrees in global average temperature does not sound like much, global average temperature during the last ice age was only about 4 to 5 °C (7 to 9 °F) colder than now. Global warming of just a few degrees will be associated with widespread changes in regional and local temperature and rainfall as well as with increases in some types of extreme weather events. These and other changes (such as sea level rise and storm surges) will have serious impacts on human societies and the natural world.

## 18. What are scientists doing to address key uncertainties in our understanding of the climate system?

Science is a continual process of observation, understanding, modelling, and testing. The prediction of a long-term trend in global warming from increasing greenhouse gases is robust and has been confirmed by a growing body of evidence. Nevertheless, understanding (for example, of cloud dynamics) remains incomplete. All of these are areas of active research.

## 19. Are disaster scenarios about tipping points like 'turning off the Gulf Stream' and release of methane from the Arctic a cause for concern?

Results from the best available climate models do not indicate any abrupt changes or 'tipping points' in the climate in the near future. However as warming increases, the possibilities of major abrupt change cannot be ruled out.

## 20. If emissions of greenhouse gases were stopped, would the climate return to the conditions of 200 years ago?

No. Even if human emissions of greenhouse gases were to suddenly stop, Earth's surface temperature would not cool and return to the level it was at before the Industrial Revolution for thousands of years because $CO_2$ is only removed from the atmosphere over these very long time scales.


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