A SHORT GUIDE TO

climate science

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

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1. Is the climate warming?

Yes. Earth's average surface air temperature has increased by about 1 °C (1.8 °F) since 1900, with over half of the increase occurring since the mid-1970s. A wide range of other observations (such as reduced Arctic sea ice extent and increased ocean heat content) and indications from the natural world (such as poleward shifts of temperature-sensitive species of fish, mammals, insects, etc.) together provide incontrovertible evidence of planetary-scale warming.

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 what 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 provides the primary source of energy driving Earth's climate system, but its variations have played very little role in the climate changes observed in recent decades. Direct satellite measurements since the late 1970s show no net increase in the Sun's output, while at the same time global surface temperatures have increased.

5. What do changes in the vertical structure of the 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 in the upper atmosphere provide us with key insights into the underlying causes of climate change and reveal that 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 ocean circulation. The speed of the current climate change is faster than most of the past events, making 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 in Earth's more distant past (many millions of years ago), at which time palaeoclimatic and geological data indicate that 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. As the atmospheric concentrations of CO_2 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, as is expected from our understanding of the climate system. These shorter-term variations are mostly due to natural causes, and do not contradict our fundamental understanding that the long-term warming trend is primarily due to human-induced changes in the atmospheric levels of CO_2 and other greenhouse gases.

10. Did the slowdown of warming during the 2000s to early 2010s mean that climate change is no longer happening?

No. After the very warm year 1998 that followed the strong 1997-98 El Niño, the increase in average surface temperature slowed relative to the previous decade of rapid temperature increases. Despite the slower rate of warming, the 2000s were warmer than the 1990s. The limited period of slower warming ended with a dramatic jump to warmer temperatures between 2014 and 2015, with all the years from 2015-2019 warmer than any preceding year in the instrumental record. A short-term slowdown in the warming of Earth's surface does not invalidate our understanding of long-term changes in global temperature arising from human-induced changes in greenhouse gases.

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 decreasing while Antarctic sea ice has changed little?

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 climate and sea ice change in the 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-caused greenhouse gas emissions. This gives the potential for more energy for storms and certain extreme weather events. Consistent with theoretical expectations, the types of events most closely related to temperature, such as heatwaves and extremely hot days, are becoming more likely. Heavy rainfall and snowfall events (which increase the risk of flooding) are also generally becoming more frequent.

14. How fast is sea level rising?

Long-term measurements of tide gauges and recent satellite data show that global sea level is rising, with the best estimate of the rate of global-average rise over the last decade being 3.6 mm per year (0.14 inches per year). The rate of sea level rise has increased since measurements using altimetry from space were started in 1992; the dominant factor in global-average sea level rise since 1970 is human-caused warming. The overall observed rise since 1902 is about 16 cm (6 inches) [Figure 6].

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

Direct observations of ocean chemistry have shown that the chemical balance of seawater has shifted to a more acidic state (lower pH). Some marine organisms (such as corals and some shellfish) have shells composed of calcium carbonate, which dissolves more readily in acid. As the acidity of sea water increases, it becomes more difficult for these organisms to form or maintain their shells.

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

Very confident. If emissions continue on their present trajectory, without either technological or regulatory abatement, 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 during the 21st century.

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 precipitation as well as with increases in some types of extreme weather events. These and other changes (such as sea level rise and storm surge) 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, testing, and prediction. 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 of certain aspects of climate change remains incomplete. Examples include natural climate variations on decadal-to-centennial timescales and regional-to-local spatial scales and cloud responses to climate change, which are all 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 predict an abrupt change in (or collapse of) the Atlantic Meridional Overturning Circulation, which includes the Gulf Stream, in the near future. However, this and other potential high-risk abrupt changes, like the release of methane and carbon dioxide from thawing permafrost, remain active areas of scientific research. Some abrupt changes are already underway, such as the decrease in Arctic sea ice extent (see Question 12), and as warming increases, the possibility of other major abrupt changes 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 emissions of greenhouse gases were to suddenly stop, Earth’s surface temperature would require thousands of years to cool and return to the level in the pre-industrial era.

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