Frequently Asked Questions

FAQ

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These Frequently Asked Questions have been extracted from the chapters of the underlying report and are compiled here. When referencing specific FAQs, please reference the corresponding chapter in the report from where the FAQ originated (e.g., FAQ 3.1 is part of Chapter 3).

Frequently Asked Questions

FAQ 1.1 | Do We Understand Climate Change Better Now Compared to When the IPCC Started?

Yes, much better. The first IPCC report, released in 1990, concluded that human-caused climate change would soon become evident, but could not yet confirm that it was already happening. Today, evidence is overwhelming that the climate has indeed changed since the pre-industrial era and that human activities are the principal cause of that change. With much more data and better models, we also understand more about how the atmosphere interacts with the ocean, ice, snow, ecosystems and land surfaces of the Earth. Computer climate simulations have also improved dramatically, incorporating many more natural processes and providing projections at much higher resolutions.

Since the first IPCC report in 1990, large numbers of new instruments have been deployed to collect data in the air, on land, at sea and from outer space. These instruments measure temperature, clouds, winds, ice, snow, ocean currents, sea level, soot and dust in the air, and many other aspects of the climate system. New satellite instruments have also provided a wealth of increasingly fine-grained data. Additional data from older observing systems and even hand-written historical records are still being incorporated into observational datasets, and these datasets are now better integrated and adjusted for historical changes in instruments and measurement techniques. Ice cores, sediments, fossils, and other new evidence from the distant past have taught us much about how Earth's climate has changed throughout its history.

Understanding of climate system processes has also improved. For example, in 1990 very little was known about how the deep ocean responds to climate change. Today, reconstructions of deep-ocean temperatures extend as far back as 1871. We now know that the oceans absorb most of the excess energy trapped by greenhouse gases and that even the deep ocean is warming up. As another example, in 1990, relatively little was known about exactly how or when the gigantic ice sheets of Greenland and Antarctica would respond to warming. Today, much more data and better models of ice-sheet behaviour reveal unexpectedly high melt rates that will lead to major changes within this century, including substantial sea level rise (FAQ 9.2).

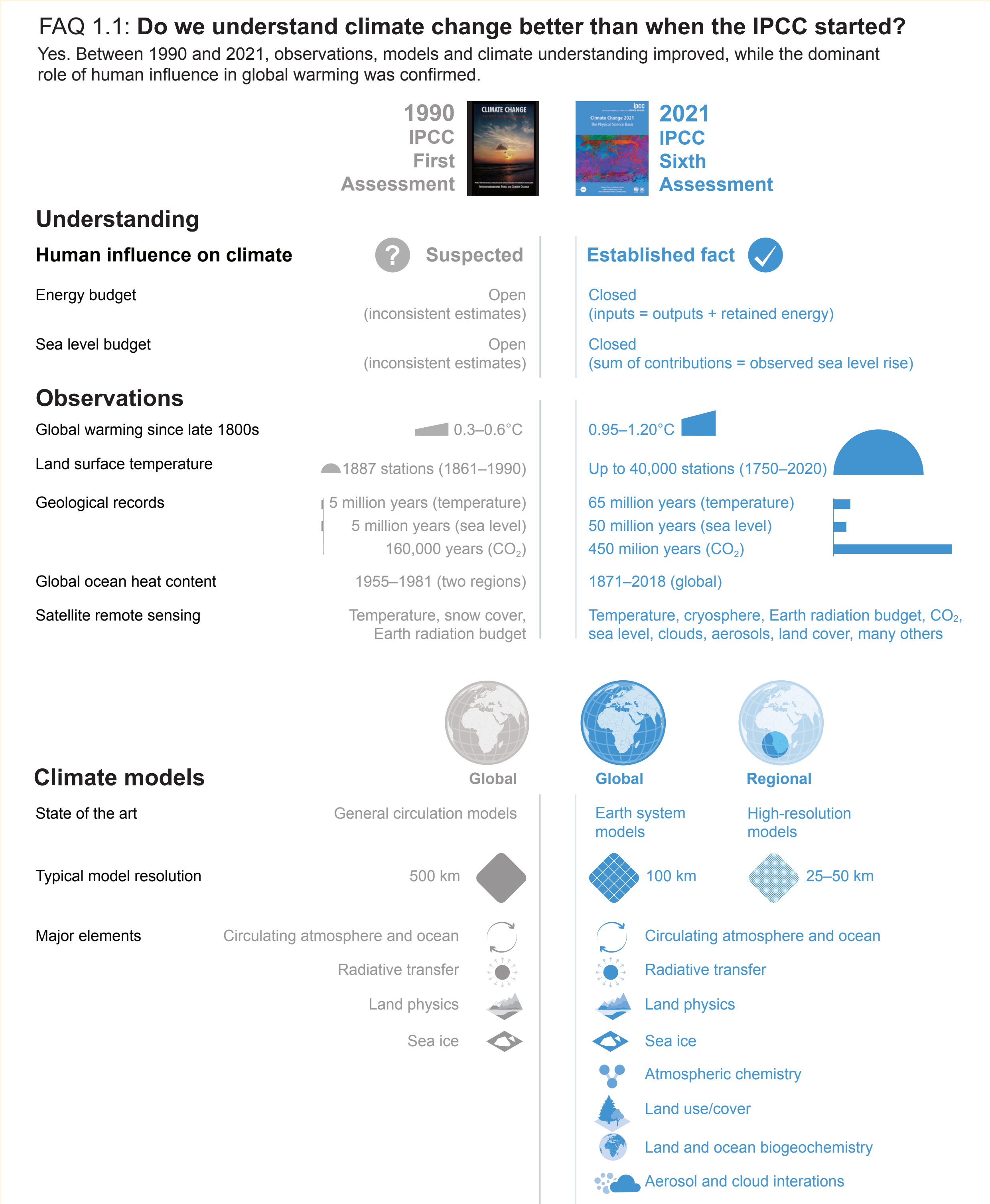
The major natural factors contributing to climate change on time scales of decades to centuries are volcanic eruptions and variations in the sun's energy output. Today, data show that changes in incoming solar energy since 1900 have contributed only slightly to global warming, and they exhibit a slight downward trend since the 1970s. Data also show that major volcanic eruptions have sometimes cooled the entire planet for relatively short periods of time (typically several years) by erupting aerosols (tiny airborne particles) high into the atmosphere.

The main human causes of climate change are the heat-absorbing greenhouse gases released by fossil fuel combustion, deforestation, and agriculture, which warm the planet; and aerosols such as sulphate from burning coal, which have a short-term cooling effect that partially counteracts human-caused warming. Since 1990, we have more and better observations of these human factors as well as improved historical records, resulting in more precise estimates of human influence on the climate system (FAQ 3.1).

While most climate models in 1990 focused on the atmosphere, using highly simplified representations of oceans and land surfaces, today's Earth system simulations include detailed models of oceans, ice, snow, vegetation and many other variables. An important test of models is their ability to simulate Earth's climate over the period of instrumental records (since about 1850). Several rounds of such testing have taken place since 1990, and the testing itself has become much more rigorous and extensive. As a group and at large scales, models have predicted the observed changes well in these tests (FAQ 3.3). Since there is no way to do a controlled laboratory experiment on the actual Earth, climate model simulations can also provide a kind of 'alternate Earth' to test what would have happened without human influence. Such experiments show that the observed warming would not have occurred without human influence.

Finally, physical theory predicts that human influence on the climate system should produce specific patterns of change, and we see those patterns in both observations and climate simulations. For example, nights are warming faster than days, less heat is escaping to space, and the lower atmosphere (troposphere) is warming but the upper atmosphere (stratosphere) has cooled. These confirmed predictions are all evidence of changes driven primarily by increases in GHG concentrations rather than natural causes.

FAQ 1.1 (continued)



FAQ 1.1, Figure 1 | Sample elements of climate understanding, observations and models as assessed in the IPCC First Assessment Report (1990) and Sixth Assessment Report (2021). Many other advances since 1990, such as key aspects of theoretical understanding, geological records and attribution of change to human influence, are not included in this figure because they are not readily represented in this simple format. Fuller explanations of the history of climate knowledge are available in the introductory chapters of the IPCC Fourth and Sixth assessment reports.

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FAQ 1.2 | Where Is Climate Change Most Apparent?

The signs of climate change are unequivocal at the global scale and are increasingly apparent on smaller spatial scales. The high northern latitudes show the largest temperature increase, with clear effects on sea ice and glaciers. The warming in the tropical regions is also apparent because the natural year-to-year variations in temperature there are small. Long-term changes in other variables such as rainfall and some weather and climate extremes have also now become apparent in many regions.

It was first noticed that the planet's land areas were warming in the 1930s. Although increasing atmospheric carbon dioxide (CO_2) concentrations were suggested as part of the explanation, it was not certain at the time whether the observed warming was part of a long-term trend or a natural fluctuation: global warming had not yet become apparent. But the planet continued to warm, and by the 1980s the changes in temperature had become obvious or, in other words, the *signal* had *emerged*.

Imagine you had been monitoring temperatures at the same location for the past 150 years. What would you have experienced? When would the warming have become noticeable in your data? The answers to these questions depend on where on the planet you are.

Observations and climate model simulations both demonstrate that the largest long-term warming trends are in the high northern latitudes and the smallest warming trends over land are in tropical regions. However, the year-to-year variations in temperature are smallest in the tropics, meaning that the changes there are also apparent, relative to the range of past experiences (FAQ 1.2, Figure 1).

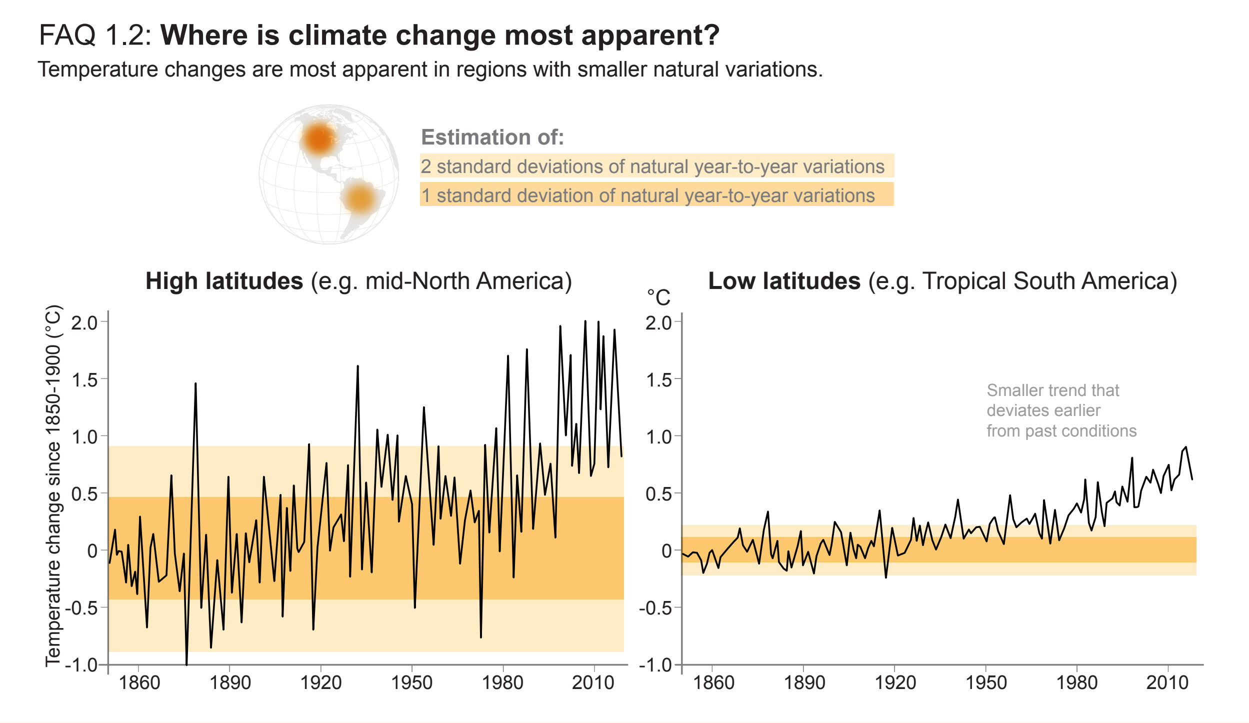
Changes in temperature also tend to be more apparent over land areas than over the open ocean and are often most apparent in regions which are more vulnerable to climate change. It is expected that future changes will continue to show the largest signals at high northern latitudes, but with the most apparent warming in the tropics. The tropics also stand to benefit the most from climate change mitigation in this context, as limiting global warming will also limit how far the climate shifts relative to past experience.

Changes in other climate variables have also become apparent at smaller spatial scales. For example, changes in average rainfall are becoming clear in some regions, but not in others, mainly because natural year-to-year variations in precipitation tend to be large relative to the magnitude of the long-term trends. However, extreme rainfall is becoming more intense in many regions, potentially increasing the impacts from inland flooding (FAQ 8.2). Sea levels are also clearly rising on many coastlines, increasing the impacts of inundation from coastal storm surges, even without any increase in the number of storms reaching land. A decline in the amount of Arctic sea ice is apparent, both in the area covered and in its thickness, with implications for polar ecosystems.

When considering climate-related impacts, it is not necessarily the size of the change that is most important. Instead, it can be the rate of change or it can also be the size of the change relative to the natural variations of the climate to which ecosystems and society are adapted. As the climate is pushed further away from past experiences and enters an unprecedented state, the impacts can become larger, along with the challenge of adapting to them.

How and when a long-term trend becomes distinguishable from shorter-term natural variations depends on the aspect of climate being considered (e.g., temperature, rainfall, sea ice or sea level), the region being considered, the rate of change, and the magnitude and timing of natural variations. When assessing the local impacts from climate change, both the size of the change and the amplitude of natural variations matter.

FAQ 1.2 (continued)



FAQ 1.2, Figure 1 | Observed variations in regional temperatures since 1850 (data from Berkeley Earth). Regions in high latitudes, such as mid-North America (40°N–64°N, 140°W–60°W, **left**), have warmed by a larger amount than regions at lower latitudes, such as tropical South America (10°S–10°N, 84°W–16°W, **right**), but the natural variations are also much larger at high latitudes (darker and lighter shading represents 1 and 2 standard deviations, respectively, of natural year-to-year variations). The signal of observed temperature change emerged earlier in tropical South America than mid-North America even though the changes were of a smaller magnitude. (Note that those regions were chosen because of the longer length of their observational record; see Figure 1.14 for more regions).

Frequently Asked Questions

FAQ 1.3 | What Can Past Climate Teach Us About the Future?

In the past, the Earth has experienced prolonged periods of elevated greenhouse gas concentrations that caused global temperatures and sea levels to rise. Studying these past warm periods informs us about the potential long-term consequences of increasing greenhouse gases in the atmosphere.

Rising greenhouse gas concentrations are driving profound changes to the Earth system, including global warming, sea level rise, increases in climate and weather extremes, ocean acidification, and ecological shifts (FAQ 2.2 and FAQ 7.1). The vast majority of instrumental observations of climate began during the 20th century, when greenhouse gas emissions from human activities became the dominant driver of changes in Earth's climate (FAQ 3.1).

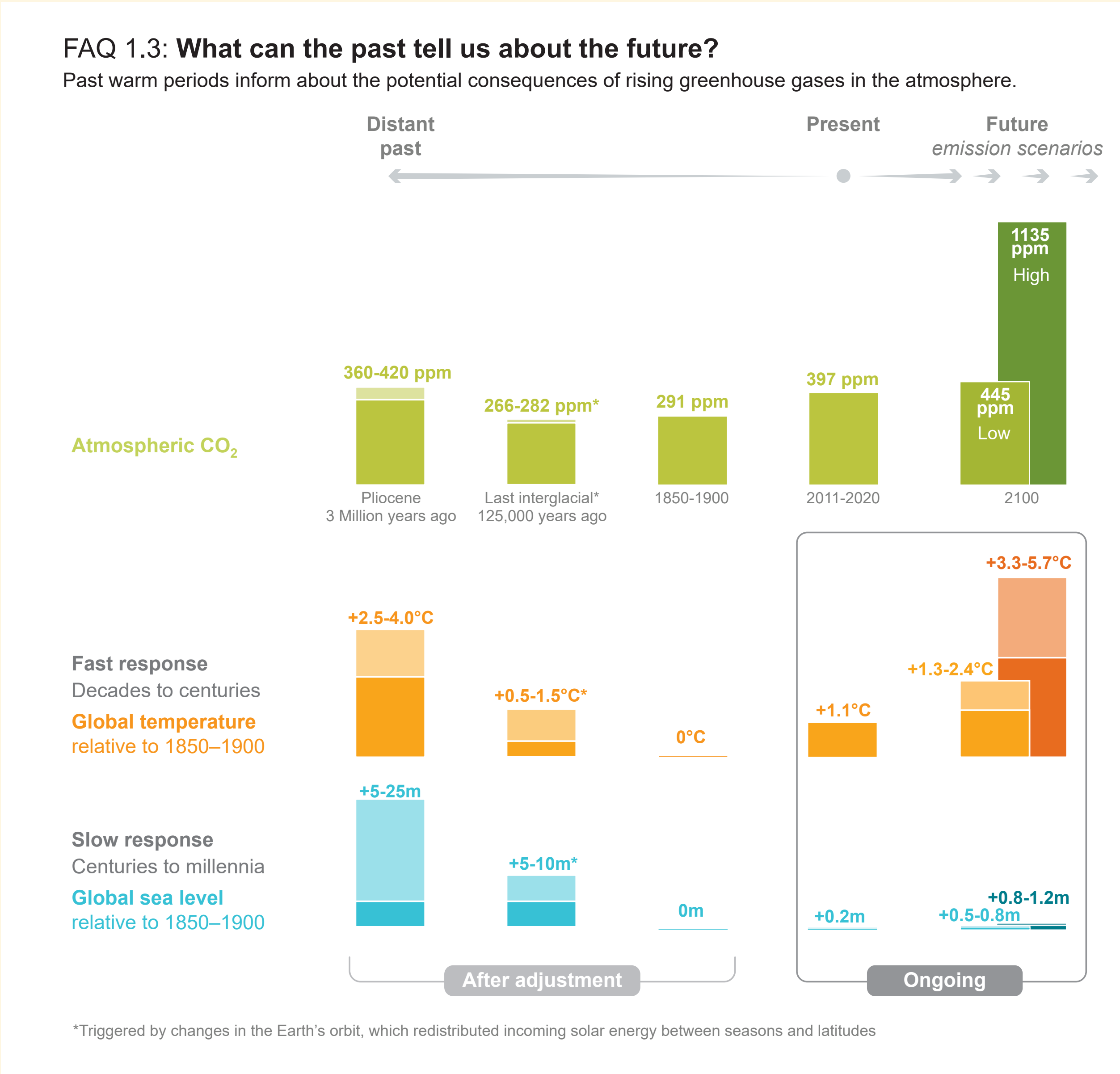
As scientists seek to refine our understanding of Earth's climate system and how it may evolve in coming decades to centuries, past climate states provide a wealth of insights. Data about these past states help to establish the relationship between natural climate drivers and the history of changes in global temperature, global sea levels, the carbon cycle, ocean circulation, and regional climate patterns, including climate extremes. Guided by such data, scientists use Earth system models to identify the chain of events underlying the transitions between past climatic states (FAQ 3.3). This is important because during present-day climate change, just as in past climate changes, some aspects of the Earth system (e.g., surface temperature) respond to changes in greenhouse gases on a time scale of decades to centuries, while others (e.g., sea level and the carbon cycle) respond over centuries to millennia (FAQ 5.3). In this way, past climate states serve as critical benchmarks for climate model simulations, improving our understanding of the sequences, rates, and magnitude of future climate change over the next decades to millennia.

Analyzing previous warm periods caused by natural factors can help us understand how key aspects of the climate system evolve in response to warming. For example, one previous warm-climate state occurred roughly 125,000 years ago, during the Last Interglacial period, when slight variations in the Earth's orbit triggered a sequence of changes that caused about 1°C–2°C of global warming and about 2–8 m of sea level rise relative to the 1850–1900, even though atmospheric carbon dioxide concentrations were similar to 1850–1900 values (FAQ 1.3, Figure 1). Modelling studies highlight that increased summer heating in the higher latitudes of the Northern Hemisphere during this time caused widespread melting of snow and ice, reducing the reflectivity of the planet and increasing the absorption of solar energy by the Earth's surface. This gave rise to global-scale warming, which led in turn to further ice loss and sea level rise. These self-reinforcing positive *feedback cycles* are a pervasive feature of Earth's climate system, with clear implications for future climate change under continued greenhouse gas emissions. In the case of sea level rise, these cycles evolved over several centuries to millennia, reminding us that the rates and magnitude of sea level rise in the 21st century are just a fraction of the sea level rise that will ultimately occur after the Earth system fully adjusts to current levels of global warming.

Roughly 3 million years ago, during the Pliocene Epoch, the Earth witnessed a prolonged period of elevated temperatures (2.5°C–4°C higher than 1850–1900) and higher sea levels (5–25 m higher than 1850–1900), in combination with atmospheric carbon dioxide concentrations similar to those of the present day. The fact that Pliocene atmospheric carbon dioxide concentrations were similar to the present, while global temperatures and sea levels were significantly higher, reflects the difference between an Earth system that has fully adjusted to changes in natural drivers (the Pliocene) and one where greenhouse gases concentrations, temperature, and sea level rise are still increasing (present day). Much about the transition into the Pliocene climate state – in terms of key causes, the role of cycles that hastened or slowed the transition, and the rate of change in climate indicators such as sea level – remain topics of intense study by climate researchers, using a combination of paleoclimate observations and Earth system models. Insights from such studies may help to reduce the large uncertainties around estimates of global sea level rise by 2300, which range from 0.3 m to 3 m above 1850–1900 (in a low-emissions scenario) to as much as 16 m higher than 1850–1900 (in a very high-emissions scenario that includes accelerating structural disintegration of the polar ice sheets).

While present-day warming is unusual in the context of the recent geologic past in several different ways (FAQ 2.1), past warm climate states present a stark reminder that the long-term adjustment to present-day atmospheric carbon dioxide concentrations has only just begun. That adjustment will continue over the coming centuries to millennia.

FAQ 1.3 (continued)



FAQ 1.3, Figure 1 | Comparison of past, present and future. Schematic of atmospheric carbon dioxide concentrations, global temperature, and global sea level during previous warm periods as compared to 1850–1900, present-day (2011–2020), and future (2100) climate change scenarios corresponding to low-emissions scenarios (SSP1-2.6; lighter colour bars) and very high-emissions scenarios (SSP5-8.5; darker colour bars).