

## Frequently Asked Question 9.2

# Can the Warming of the 20th Century be Explained by Natural Variability?

*It is very unlikely that the 20th-century warming can be explained by natural causes. The late 20th century has been unusually warm. Palaeoclimatic reconstructions show that the second half of the 20th century was likely the warmest 50-year period in the Northern Hemisphere in the last 1300 years. This rapid warming is consistent with the scientific understanding of how the climate should respond to a rapid increase in greenhouse gases like that which has occurred over the past century, and the warming is inconsistent with the scientific understanding of how the climate should respond to natural external factors such as variability in solar output and volcanic activity. Climate models provide a suitable tool to study the various influences on the Earth's climate. When the effects of increasing levels of greenhouse gases are included in the models, as well as natural external factors, the models produce good simulations of the warming that has occurred over the past century. The models fail to reproduce the observed warming when run using only natural factors. When human factors are included, the models also simulate a geographic pattern of temperature change around the globe similar to that which has occurred in recent decades. This spatial pattern, which has features such as a greater warming at high northern latitudes, differs from the most important patterns of natural climate variability that are associated with internal climate processes, such as El Niño.*

Variations in the Earth's climate over time are caused by natural internal processes, such as El Niño, as well as changes in external influences. These external influences can be natural in origin, such as volcanic activity and variations in solar output, or caused by human activity, such as greenhouse gas emissions, human-sourced aerosols, ozone depletion and land use change. The role of natural internal processes can be estimated by studying observed variations in climate and by running climate models without changing any of the external factors that affect climate. The effect of external influences can be estimated with models by changing these factors, and by using physical understanding of the processes involved. The combined effects of natural internal variability and natural external factors can also be estimated from climate information recorded in tree rings, ice cores and other types of natural 'thermometers' prior to the industrial age.

The natural external factors that affect climate include volcanic activity and variations in solar output. Explosive volcanic eruptions occasionally eject large amounts of dust and sulphate aerosol high into the atmosphere, temporarily shielding the Earth and reflecting sunlight back to space. Solar output has an 11-year cycle and may also have longer-term variations. Human activities over the last 100 years, particularly the burning of fossil fuels, have caused a rapid increase in carbon dioxide and other greenhouse gases in the atmosphere. Before

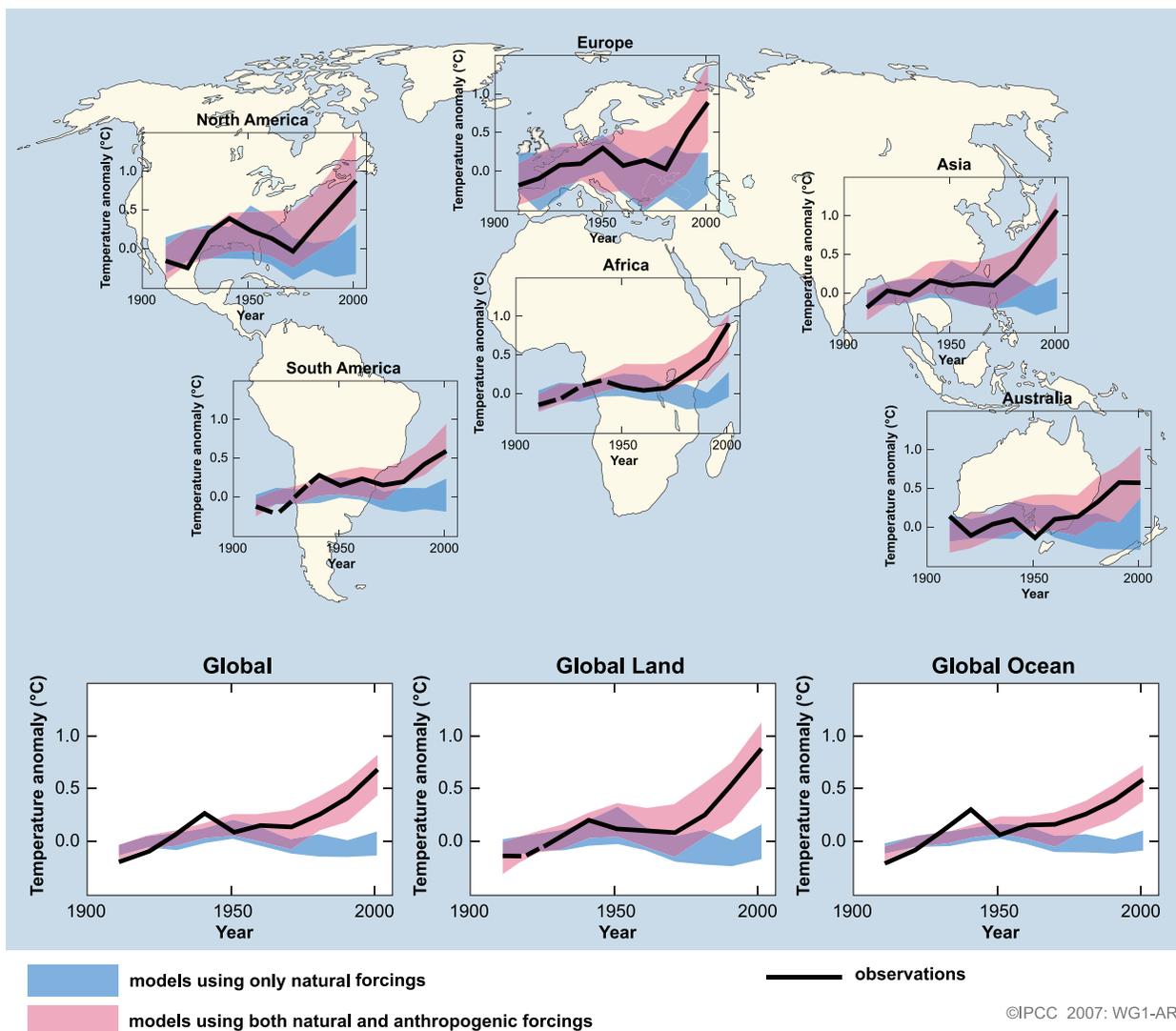
the industrial age, these gases had remained at near stable concentrations for thousands of years. Human activities have also caused increased concentrations of fine reflective particles, or 'aerosols', in the atmosphere, particularly during the 1950s and 1960s.

Although natural internal climate processes, such as El Niño, can cause variations in global mean temperature for relatively short periods, analysis indicates that a large portion is due to external factors. Brief periods of global cooling have followed major volcanic eruptions, such as Mt. Pinatubo in 1991. In the early part of the 20th century, global average temperature rose, during which time greenhouse gas concentrations started to rise, solar output was probably increasing and there was little volcanic activity. During the 1950s and 1960s, average global temperatures levelled off, as increases in aerosols from fossil fuels and other sources cooled the planet. The eruption of Mt. Agung in 1963 also put large quantities of reflective dust into the upper atmosphere. The rapid warming observed since the 1970s has occurred in a period when the increase in greenhouse gases has dominated over all other factors.

Numerous experiments have been conducted using climate models to determine the likely causes of the 20th-century climate change. These experiments indicate that models cannot reproduce the rapid warming observed in recent decades when they only take into account variations in solar output and volcanic activity. However, as shown in Figure 1, models are able to simulate the observed 20th-century changes in temperature when they include all of the most important external factors, including human influences from sources such as greenhouse gases and natural external factors. The model-estimated responses to these external factors are detectable in the 20th-century climate globally and in each individual continent except Antarctica, where there are insufficient observations. The human influence on climate very likely dominates over all other causes of change in global average surface temperature during the past half century.

An important source of uncertainty arises from the incomplete knowledge of some external factors, such as human-sourced aerosols. In addition, the climate models themselves are imperfect. Nevertheless, all models simulate a pattern of response to greenhouse gas increases from human activities that is similar to the observed pattern of change. This pattern includes more warming over land than over the oceans. This pattern of change, which differs from the principal patterns of temperature change associated with natural internal variability, such as El Niño, helps to distinguish the response to greenhouse gases from that of natural external factors. Models and observations also both show warming in the lower part of

*(continued)*



**FAQ 9.2, Figure 1.** Temperature changes relative to the corresponding average for 1901-1950 (°C) from decade to decade from 1906 to 2005 over the Earth's continents, as well as the entire globe, global land area and the global ocean (lower graphs). The black line indicates observed temperature change, while the coloured bands show the combined range covered by 90% of recent model simulations. Red indicates simulations that include natural and human factors, while blue indicates simulations that include only natural factors. Dashed black lines indicate decades and continental regions for which there are substantially fewer observations. Detailed descriptions of this figure and the methodology used in its production are given in the Supplementary Material, Appendix 9.C.

the atmosphere (the troposphere) and cooling higher up in the stratosphere. This is another ‘fingerprint’ of change that reveals the effect of human influence on the climate. If, for example, an increase in solar output had been responsible for the recent climate warming, both the troposphere and the stratosphere would have warmed. In addition, differences in the timing of the human and natural external influences help to distinguish the climate responses to these factors. Such considerations increase confidence that human rather than natural factors were the dominant cause of the global warming observed over the last 50 years.

Estimates of Northern Hemisphere temperatures over the last one to two millennia, based on natural ‘thermometers’ such as tree rings that vary in width or density as temperatures change, and historical weather records, provide additional evidence that

the 20th-century warming cannot be explained by only natural internal variability and natural external forcing factors. Confidence in these estimates is increased because prior to the industrial era, much of the variation they show in Northern Hemisphere average temperatures can be explained by episodic cooling caused by large volcanic eruptions and by changes in the Sun’s output. The remaining variation is generally consistent with the variability simulated by climate models in the absence of natural and human-induced external factors. While there is uncertainty in the estimates of past temperatures, they show that it is likely that the second half of the 20th century was the warmest 50-year period in the last 1300 years. The estimated climate variability caused by natural factors is small compared to the strong 20th-century warming.

**From the report accepted by Working Group I  
of the Intergovernmental Panel on Climate Change  
but not approved in detail**

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## **Frequently Asked Questions**

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