

## Frequently Asked Question 8.1

# How Reliable Are the Models Used to Make Projections of Future Climate Change?

*There is considerable confidence that climate models provide credible quantitative estimates of future climate change, particularly at continental scales and above. This confidence comes from the foundation of the models in accepted physical principles and from their ability to reproduce observed features of current climate and past climate changes. Confidence in model estimates is higher for some climate variables (e.g., temperature) than for others (e.g., precipitation). Over several decades of development, models have consistently provided a robust and unambiguous picture of significant climate warming in response to increasing greenhouse gases.*

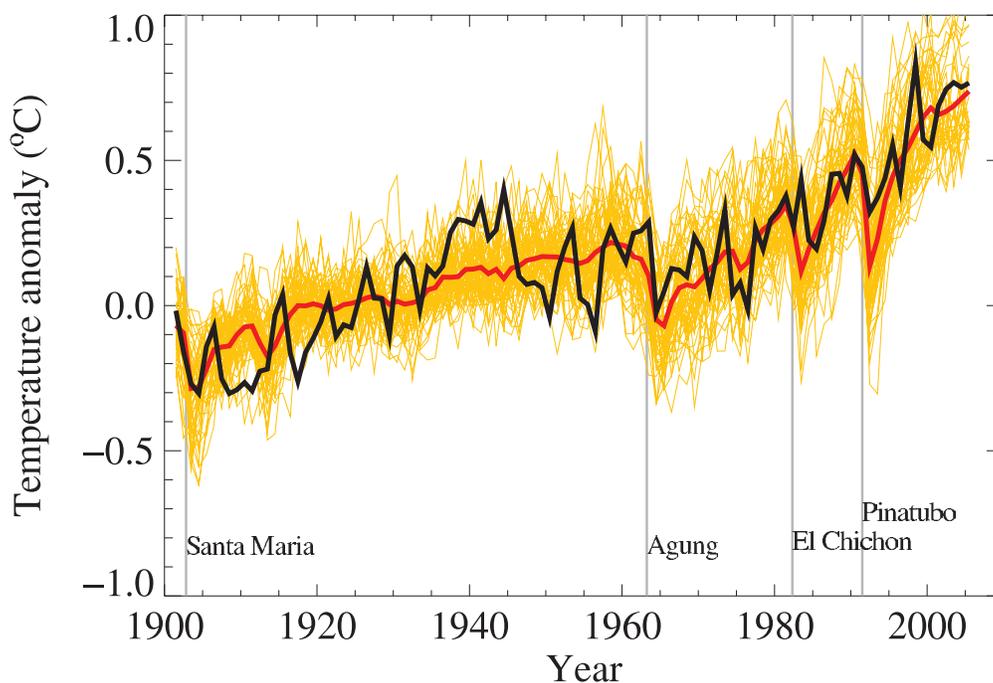
Climate models are mathematical representations of the climate system, expressed as computer codes and run on powerful computers. One source of confidence in models comes from the fact that model fundamentals are based on established physical laws, such as conservation of mass, energy and momentum, along with a wealth of observations.

A second source of confidence comes from the ability of models to simulate important aspects of the current climate. Models are routinely and extensively assessed by comparing their simulations with observations of the atmosphere, ocean, cryosphere and land surface. Unprecedented levels of evaluation have taken place over the last decade in the form of organised multi-model ‘intercomparisons’. Models show significant and

increasing skill in representing many important mean climate features, such as the large-scale distributions of atmospheric temperature, precipitation, radiation and wind, and of oceanic temperatures, currents and sea ice cover. Models can also simulate essential aspects of many of the patterns of climate variability observed across a range of time scales. Examples include the advance and retreat of the major monsoon systems, the seasonal shifts of temperatures, storm tracks and rain belts, and the hemispheric-scale seesawing of extratropical surface pressures (the Northern and Southern ‘annular modes’). Some climate models, or closely related variants, have also been tested by using them to predict weather and make seasonal forecasts. These models demonstrate skill in such forecasts, showing they can represent important features of the general circulation across shorter time scales, as well as aspects of seasonal and interannual variability. Models’ ability to represent these and other important climate features increases our confidence that they represent the essential physical processes important for the simulation of future climate change. (Note that the limitations in climate models’ ability to forecast weather beyond a few days do not limit their ability to predict long-term climate changes, as these are very different types of prediction – see FAQ 1.2.)

*(continued)*

**FAQ 8.1, Figure 1.** Global mean near-surface temperatures over the 20th century from observations (black) and as obtained from 58 simulations produced by 14 different climate models driven by both natural and human-caused factors that influence climate (yellow). The mean of all these runs is also shown (thick red line). Temperature anomalies are shown relative to the 1901 to 1950 mean. Vertical grey lines indicate the timing of major volcanic eruptions. (Figure adapted from Chapter 9, Figure 9.5. Refer to corresponding caption for further details.)



A third source of confidence comes from the ability of models to reproduce features of past climates and climate changes. Models have been used to simulate ancient climates, such as the warm mid-Holocene of 6,000 years ago or the last glacial maximum of 21,000 years ago (see Chapter 6). They can reproduce many features (allowing for uncertainties in reconstructing past climates) such as the magnitude and broad-scale pattern of oceanic cooling during the last ice age. Models can also simulate many observed aspects of climate change over the instrumental record. One example is that the global temperature trend over the past century (shown in Figure 1) can be modelled with high skill when both human and natural factors that influence climate are included. Models also reproduce other observed changes, such as the faster increase in nighttime than in daytime temperatures, the larger degree of warming in the Arctic and the small, short-term global cooling (and subsequent recovery) which has followed major volcanic eruptions, such as that of Mt. Pinatubo in 1991 (see FAQ 8.1, Figure 1). Model global temperature projections made over the last two decades have also been in overall agreement with subsequent observations over that period (Chapter 1).

Nevertheless, models still show significant errors. Although these are generally greater at smaller scales, important large-scale problems also remain. For example, deficiencies remain in the simulation of tropical precipitation, the El Niño-Southern Oscillation and the Madden-Julian Oscillation (an observed variation in tropical winds and rainfall with a time scale of 30 to 90 days). The ultimate source of most such errors is that many important small-scale processes cannot be represented explicitly in models, and so must be included in approximate form as they interact with larger-scale features. This is partly due to limitations in computing power, but also results from limitations in scientific understanding or in the availability of detailed observations of some physical processes. Significant uncertainties, in particular, are associated with the representation of clouds, and in the resulting cloud responses to climate change. Consequently, models continue to display a substantial range of global temperature change in response to specified greenhouse gas forcing (see Chapter 10). Despite such uncertainties, however, models are unanimous in their

prediction of substantial climate warming under greenhouse gas increases, and this warming is of a magnitude consistent with independent estimates derived from other sources, such as from observed climate changes and past climate reconstructions.

Since confidence in the changes projected by global models decreases at smaller scales, other techniques, such as the use of regional climate models, or downscaling methods, have been specifically developed for the study of regional- and local-scale climate change (see FAQ 11.1). However, as global models continue to develop, and their resolution continues to improve, they are becoming increasingly useful for investigating important smaller-scale features, such as changes in extreme weather events, and further improvements in regional-scale representation are expected with increased computing power. Models are also becoming more comprehensive in their treatment of the climate system, thus explicitly representing more physical and biophysical processes and interactions considered potentially important for climate change, particularly at longer time scales. Examples are the recent inclusion of plant responses, ocean biological and chemical interactions, and ice sheet dynamics in some global climate models.

In summary, confidence in models comes from their physical basis, and their skill in representing observed climate and past climate changes. Models have proven to be extremely important tools for simulating and understanding climate, and there is considerable confidence that they are able to provide credible quantitative estimates of future climate change, particularly at larger scales. Models continue to have significant limitations, such as in their representation of clouds, which lead to uncertainties in the magnitude and timing, as well as regional details, of predicted climate change. Nevertheless, over several decades of model development, they have consistently provided a robust and unambiguous picture of significant climate warming in response to increasing greenhouse gases.

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**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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