

Frequently Asked Questions

FAQ 12.1 | Why Are So Many Models and Scenarios Used to Project Climate Change?

Future climate is partly determined by the magnitude of future emissions of greenhouse gases, aerosols and other natural and man-made forcings. These forcings are external to the climate system, but modify how it behaves. Future climate is shaped by the Earth's response to those forcings, along with internal variability inherent in the climate system. A range of assumptions about the magnitude and pace of future emissions helps scientists develop different emission scenarios, upon which climate model projections are based. Different climate models, meanwhile, provide alternative representations of the Earth's response to those forcings, and of natural climate variability. Together, ensembles of models, simulating the response to a range of different scenarios, map out a range of possible futures, and help us understand their uncertainties.

Predicting socioeconomic development is arguably even more difficult than predicting the evolution of a physical system. It entails predicting human behaviour, policy choices, technological advances, international competition and cooperation. The common approach is to use scenarios of plausible future socioeconomic development, from which future emissions of greenhouse gases and other forcing agents are derived. It has not, in general, been possible to assign likelihoods to individual forcing scenarios. Rather, a set of alternatives is used to span a range of possibilities. The outcomes from different forcing scenarios provide policymakers with alternatives and a range of possible futures to consider.

Internal fluctuations in climate are spontaneously generated by interactions between components such as the atmosphere and the ocean. In the case of near-term climate change, they may eclipse the effect of external perturbations, like greenhouse gas increases (see Chapter 11). Over the longer term, however, the effect of external forcings is expected to dominate instead. Climate model simulations project that, after a few decades, different scenarios of future anthropogenic greenhouse gases and other forcing agents—and the climate system's response to them—will differently affect the change in mean global temperature (FAQ 12.1, Figure 1, left panel). Therefore, evaluating the consequences of those various scenarios and responses is of paramount importance, especially when policy decisions are considered.

Climate models are built on the basis of the physical principles governing our climate system, and empirical understanding, and represent the complex, interacting processes needed to simulate climate and climate change, both past and future. Analogues from past observations, or extrapolations from recent trends, are inadequate strategies for producing projections, because the future will not necessarily be a simple continuation of what we have seen thus far.

Although it is possible to write down the equations of fluid motion that determine the behaviour of the atmosphere and ocean, it is impossible to solve them without using numerical algorithms through computer model simulation, similarly to how aircraft engineering relies on numerical simulations of similar types of equations. Also, many small-scale physical, biological and chemical processes, such as cloud processes, cannot be described by those equations, either because we lack the computational ability to describe the system at a fine enough resolution to directly simulate these processes or because we still have a partial scientific understanding of the mechanisms driving these processes. Those need instead to be approximated by so-called parameterizations within the climate models, through which a mathematical relation between directly simulated and approximated quantities is established, often on the basis of observed behaviour.

There are various alternative and equally plausible numerical representations, solutions and approximations for modelling the climate system, given the limitations in computing and observations. This diversity is considered a healthy aspect of the climate modelling community, and results in a range of plausible climate change projections at global and regional scales. This range provides a basis for quantifying uncertainty in the projections, but because the number of models is relatively small, and the contribution of model output to public archives is voluntary, the sampling of possible futures is neither systematic nor comprehensive. Also, some inadequacies persist that are common to all models; different models have different strengths and weaknesses; it is not yet clear which aspects of the quality of the simulations that can be evaluated through observations should guide our evaluation of future model simulations. *(continued on next page)*

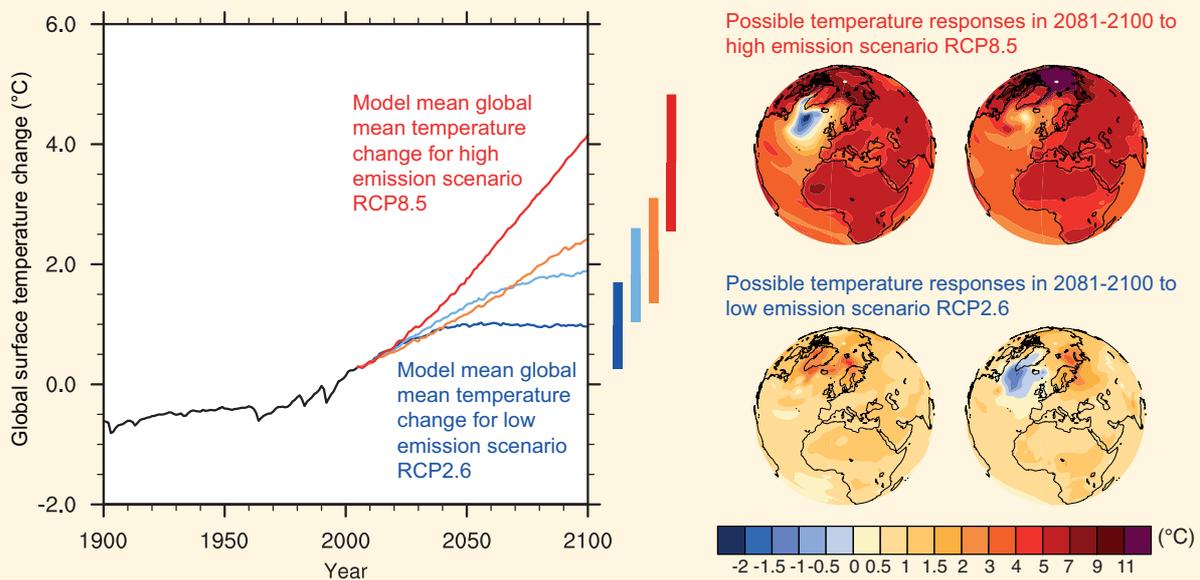
FAQ 12.1 (continued)

Models of varying complexity are commonly used for different projection problems. A faster model with lower resolution, or a simplified description of some climate processes, may be used in cases where long multi-century simulations are required, or where multiple realizations are needed. Simplified models can adequately represent large-scale average quantities, like global average temperature, but finer details, like regional precipitation, can be simulated only by complex models.

The coordination of model experiments and output by groups such as the Coupled Model Intercomparison Project (CMIP), the World Climate Research Program and its Working Group on Climate Models has seen the science community step up efforts to evaluate the ability of models to simulate past and current climate and to compare future climate change projections. The ‘multi-model’ approach is now a standard technique used by the climate science community to assess projections of a specific climate variable.

FAQ 12.1, Figure 1, right panels, shows the temperature response by the end of the 21st century for two illustrative models and the highest and lowest RCP scenarios. Models agree on large-scale patterns of warming at the surface, for example, that the land is going to warm faster than ocean, and the Arctic will warm faster than the tropics. But they differ both in the magnitude of their global response for the same scenario, and in small scale, regional aspects of their response. The magnitude of Arctic amplification, for instance, varies among different models, and a subset of models show a weaker warming or slight cooling in the North Atlantic as a result of the reduction in deepwater formation and shifts in ocean currents.

There are inevitable uncertainties in future external forcings, and the climate system’s response to them, which are further complicated by internally generated variability. The use of multiple scenarios and models have become a standard choice in order to assess and characterize them, thus allowing us to describe a wide range of possible future evolutions of the Earth’s climate.



FAQ 12.1, Figure 1 | Global mean temperature change averaged across all Coupled Model Intercomparison Project Phase 5 (CMIP5) models (relative to 1986–2005) for the four Representative Concentration Pathway (RCP) scenarios: RCP2.6 (dark blue), RCP4.5 (light blue), RCP6.0 (orange) and RCP8.5 (red); 32, 42, 25 and 39 models were used respectively for these 4 scenarios. *Likely* ranges for global temperature change by the end of the 21st century are indicated by vertical bars. Note that these ranges apply to the difference between two 20-year means, 2081–2100 relative to 1986–2005, which accounts for the bars being centred at a smaller value than the end point of the annual trajectories. For the highest (RCP8.5) and lowest (RCP2.6) scenario, illustrative maps of surface temperature change at the end of the 21st century (2081–2100 relative to 1986–2005) are shown for two CMIP5 models. These models are chosen to show a rather broad range of response, but this particular set is not representative of any measure of model response uncertainty.