Frequently Asked Questions

FAQ 1.1 | If Understanding of the Climate System Has Increased, Why Hasn't the Range of Temperature Projections Been Reduced?

The models used to calculate the IPCC's temperature projections agree on the direction of future global change, but the projected size of those changes cannot be precisely predicted. Future greenhouse gas (GHG) emission rates could take any one of many possible trajectories, and some underlying physical processes are not yet completely understood, making them difficult to model. Those uncertainties, combined with natural year-to-year climate variability, produce an 'uncertainty range' in temperature projections.

The uncertainty range around projected GHG and aerosol precursor emissions (which depend on projections of future social and economic conditions) cannot be materially reduced. Nevertheless, improved understanding and climate models—along with observational constraints—may reduce the uncertainty range around some factors that influence the climate's response to those emission changes. The complexity of the climate system, however, makes this a slow process. (FAQ1.1, Figure 1)

Climate science has made many important advances since the last IPCC assessment report, thanks to improvements in measurements and data analysis in the cryosphere, atmosphere, land, biosphere and ocean systems. Scientists also have better understanding and tools to model the role of clouds, sea ice, aerosols, small-scale ocean mixing, the carbon cycle and other processes. More observations mean that models can now be evaluated more thoroughly, and projections can be better constrained. For example, as models and observational analysis have improved, projections of sea level rise have become more accurate, balancing the current sea level rise budget.

Despite these advances, there is still a range in plausible projections for future global and regional climate—what scientists call an 'uncertainty range'. These uncertainty ranges are specific to the variable being considered (precipitation vs. temperature, for instance) and the spatial and temporal extent (such as regional vs. global averages). Uncertainties in climate projections arise from natural variability and uncertainty around the rate of future emissions and the climate's response to them. They can also occur because representations of some known processes are as yet unrefined, and because some processes are not included in the models.

There are fundamental limits to just how precisely annual temperatures can be projected, because of the chaotic nature of the climate system. Furthermore, decadal-scale projections are sensitive to prevailing conditions—such as the temperature of the deep ocean—that are less well known. Some natural variability over decades arises from interactions between the ocean, atmosphere, land, biosphere and cryosphere, and is also linked to phenomena such as the El Niño-Southern Oscillation (ENSO) and the North Atlantic Oscillation (see Box 2.5 for details on patterns and indices of climate variability).

Volcanic eruptions and variations in the sun's output also contribute to natural variability, although they are externally forced and explainable. This natural variability can be viewed as part of the 'noise' in the climate record, which provides the backdrop against which the 'signal' of anthropogenic climate change is detected.

Natural variability has a greater influence on uncertainty at regional and local scales than it does over continental or global scales. It is inherent in the Earth system, and more knowledge will not eliminate the uncertainties it brings. However, some progress is possible—particularly for projections up to a few years ahead—which exploit advances in knowledge of, for instance, the cryosphere or ocean state and processes. This is an area of active research. When climate variables are averaged over decadal timescales or longer, the relative importance of internal variability diminishes, making the long-term signals more evident (FAQ1.1, Figure 1). This long-term perspective is consistent with a common definition of climate as an average over 30 years.

A second source of uncertainty stems from the many possible trajectories that future emission rates of GHGs and aerosol precursors might take, and from future trends in land use. Nevertheless, climate projections rely on input from these variables. So to obtain these estimates, scientists consider a number of alternative scenarios for future human society, in terms of population, economic and technological change, and political choices. They then estimate the likely emissions under each scenario. The IPCC informs policymaking, therefore climate projections for different emissions scenarios can be useful as they show the possible climatic consequences of different policy choices. These scenarios are intended to be compatible with the full range of emissions scenarios described in the current scientific literature, with or without climate policy. As such, they are designed to sample uncertainty in future scenarios. *(continued on next page)*

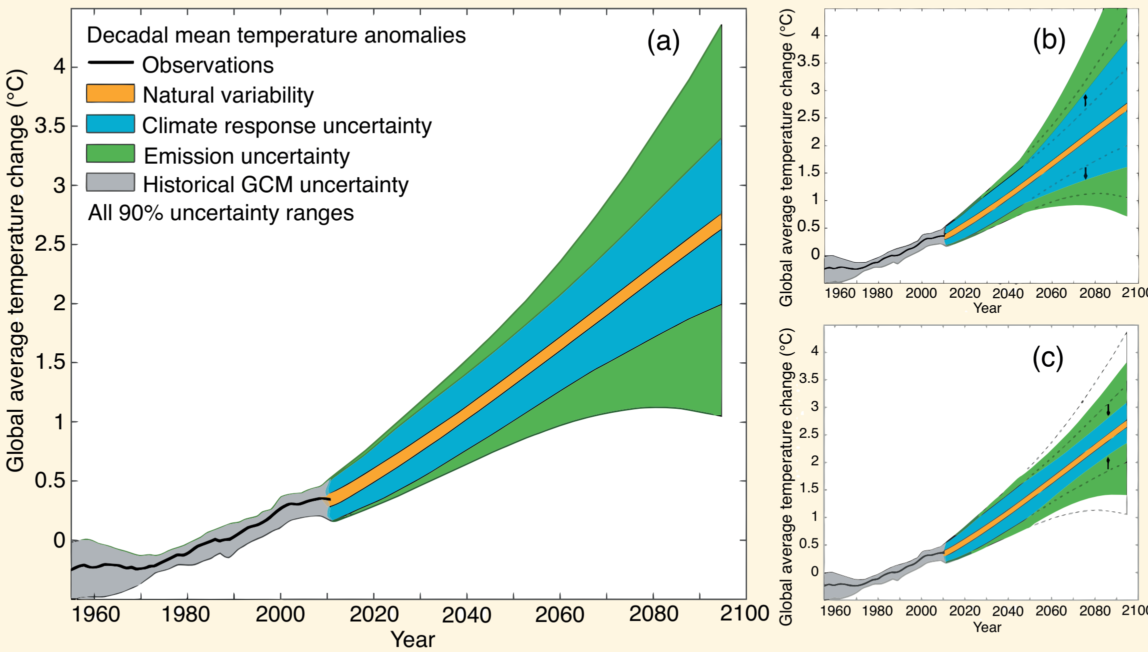
FAQ 1.1 (continued)

Projections for the next few years and decades are sensitive to emissions of short-lived compounds such as aerosols and methane. More distant projections, however, are more sensitive to alternative scenarios around long-lived GHG emissions. These scenario-dependent uncertainties will not be reduced by improvements in climate science, and will become the dominant uncertainty in projections over longer timescales (e.g., 2100) (FAQ 1.1, Figure 1).

The final contribution to the uncertainty range comes from our imperfect knowledge of how the climate will respond to future anthropogenic emissions and land use change. Scientists principally use computer-based global climate models to estimate this response. A few dozen global climate models have been developed by different groups of scientists around the world. All models are built on the same physical principles, but some approximations are needed because the climate system is so complex. Different groups choose slightly different approximations to represent specific processes in the atmosphere, such as clouds. These choices produce differences in climate projections from different models. This contribution to the uncertainty range is described as 'response uncertainty' or 'model uncertainty'.

The complexity of the Earth system means that future climate could follow many different scenarios, yet still be consistent with current understanding and models. As observational records lengthen and models improve, researchers should be able, within the limitations of the range of natural variability, to narrow that range in probable temperature in the next few decades (FAQ 1.1, Figure 1). It is also possible to use information about the current state of the oceans and cryosphere to produce better projections up to a few years ahead.

As science improves, new geophysical processes can be added to climate models, and representations of those already included can be improved. These developments can appear to increase model-derived estimates of climate response uncertainty, but such increases merely reflect the quantification of previously unmeasured sources of uncertainty (FAQ1.1, Figure 1). As more and more important processes are added, the influence of unquantified processes lessens, and there can be more confidence in the projections.



FAQ 1.1, Figure 1 | Schematic diagram showing the relative importance of different uncertainties, and their evolution in time. (a) Decadal mean surface temperature change (°C) from the historical record (black line), with climate model estimates of uncertainty for historical period (grey), along with future climate projections and uncertainty. Values are normalised by means from 1961 to 1980. Natural variability (orange) derives from model interannual variability, and is assumed constant with time. Emission uncertainty (green) is estimated as the model mean difference in projections from different scenarios. Climate response uncertainty (blue-solid) is based on climate model spread, along with added uncertainties from the carbon cycle, as well as rough estimates of additional uncertainty from poorly modelled processes. Based on Hawkins and Sutton (2011) and Huntingford et al. (2009). (b) Climate response uncertainty can appear to increase when a new process is discovered to be relevant, but such increases reflect a quantification of previously unmeasured uncertainty, or (c) can decrease with additional model improvements and observational constraints. The given uncertainty range of 90% means that the temperature is estimated to be in that range, with a probability of 90%.