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# Probabilistic future global-mean temperature changes from a simple Earth System Model

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Future global-mean temperature projections, such as those presented in the 2007 IPCC Fourth Assessment Report, typically provide a best estimate and an uncertainty range. For example, the global-mean temperature increase relative to 1990 is likely to be in the range 1.1°C to 6.4°C by 2100 (IPCC [2007]). This wide range reflects uncertainties in both future emissions and the response of combined 'physical' climate system and biogeochemical processes. However, such a wide temperature span is not particularly helpful for policy and planning purposes, especially in the absence of probabilities. This research investigates the range of uncertainty associated with future global-mean temperature change projections, taking into account interactions between the climate system, the carbon cycle and aerosols. A reduced complexity Earth System Model was selected as an appropriate tool for this research. These models are used for a number of different purposes, including climate change policy processes at national and international levels, and for evaluating emissions scenarios and stabilisation pathways. In addition, a number of integrated assessment models and regional impact studies (with pattern scaling) rely heavily on such models. Another motivation for this research is to better understand the feasibility and implications of emission scenarios that are intended to avoid 'dangerous climate change'. The risks associated with exceeding a particular temperature threshold, or limits set by a carbon budget approach can be assessed using a simple Earth System Model, appropriately calibrated against observations and more complex models. To investigate setting the climate system and carbon cycle parameters in the model, the contribution of each of the parameters to the overall uncertainty was first assessed. These model components are interrelated; this interaction is important since it affects probable global-mean surface temperature change projections. The results demonstrated that the model's carbon cycle parameters have the strongest influence on carbon dioxide concentrations at 2100, but also a considerable impact on temperature projections. The climate sensitivity also contributes to the carbon cycle uncertainty. These interactions indicate that, for any Earth System Model, estimates of the carbon cycle parameters are important for future temperature projections. Future carbon dioxide concentrations depend on anthropogenic processes that generate carbon dioxide and biogeochemical processes that cycle carbon between vegetation, ocean and atmosphere, processes that are temperature dependent. The most significant parameters were assigned prior probability distributions. These were estimated using observational constraints and previous calibration results. These 'expert priors' were then combined with twentieth-century historical climate and carbon cycle observations using a Monte Carlo Metropolis-Hastings algorithm. This produced revised posterior distributions for the key model parameters, which were then used as a basis for warming projections. Of particular significance, it was found that the model's carbon cycle parameters could be constrained in this way; previously these parameters have only been calibrated against C4MIP models. These revised parameter distributions then lead to probabilistic temperature and atmospheric carbon dioxide concentration projections for a given emissions scenario. Some examples of these results for selected emission scenarios are included.