The goal of this presentation is to provide information about future global-mean temperature and sea level change and rates of temperature change, and their uncertainties, for both no-climate-policy and policy (concentration stabilization) emissions scenarios. Future climate change is quantified for three different cases: (1) changes that are already in the system; (2) changes that are likely to occur in the absence of policies to limit (‘mitigate’) future climate change; and (3) changes that might occur if certain mitigation policies were implemented.

Changes already in the system: ‘warming commitments’.

Primarily because of the thermal inertia of the oceans, the realized climate change at any given time ‘t’ lags behind the equilibrium change that corresponds to the forcing at time ‘t’. This is similar to an accelerating motor vehicle. If the accelerator is pushed to the floor, the speed of the vehicle will lag behind the maximum speed corresponding to the accelerator’s position. Thus, if we could hold the forcing on the climate system steady at today’s level (where the forcing corresponds to the position of the accelerator pedal in the above analogy), substantial changes in climate would still occur in the future as the system slowly moved towards a new equilibrium state. The additional increase in global-mean temperature is called the ‘unrealized warming’ or the ‘warming commitment’.

Keeping the forcing level at today’s value would require keeping the concentrations (C) of all radiatively active gases and particles (aerosols) constant – so this warming commitment can be referred to as the ‘constant-C commitment’. Given that the cause of the current increases in these concentrations is increasing emissions (E) of gases like CO$_2$, CH$_4$, SO$_2$, etc., an alternative type of commitment, the constant-E commitment, may also be defined. There are also corresponding commitments to future sea level rise.

The magnitudes of these commitments depend on the magnitude of past forcing changes (both natural and anthropogenic), the climate sensitivity, and (to a lesser extent) other factors that control the inertia of the climate system. These controls are subject to considerable uncertainty, so the warming and sea level commitments are also uncertain. If concentrations were all stabilized at current levels, global-mean temperatures would initially continue to increase at the present rate (about 0.2°C/decade) and then either rapidly or gradually slow down. By 2050, the warming relative to 2000 could be as small as 0.1°C or could exceed 0.4°C. The asymptotic warming (which would be realized only after many centuries) ranges from 0.13°C to about 1°C. For sea level, an increase at 10–20cm/century would continue for many centuries. If emissions were kept constant at today’s levels, the concentrations of long-lived gases like CO$_2$ and N$_2$O would continue to increase for centuries. This would lead to further increases in temperature and sea level above the constant-C commitments. Warming would continue at 0.8–2.0°C/century and sea level would rise at 20–40cm/century for many centuries. The message here is that, to avoid substantial climate change, we must eventually reduce emissions to well below current levels. Limiting sea level rise is an even more difficult task.

Climate change in the absence of mitigation policies.

As part of the IPCC Third Assessment, a large set of no-climate-policy emissions scenarios was developed (referred to as the SRES scenarios, for ‘Special Report on Emissions Scenarios’). Temperature and sea level projections based on these scenarios were given in the Third Assessment Report (TAR) using the MAGICC climate model (Model for the Assessment of Greenhouse-gas Induced Climate Change – a user-friendly version of MAGICC can be downloaded from
In the TAR, the range of 1990–2000 global-mean warming, accounting for emissions and climate model uncertainties, was given as 1.4–5.8°C. I will show a probabilistic representation of these results, accounting additionally for uncertainties in the carbon cycle and aerosol forcing (from Wigley and Raper, 2001). The 90% confidence interval (C.I.) for 1990–2000 warming is 1.7–4.9°C (1.5–4.7°C for warming over 2000–2100).

I will also present probabilistic results for the rate of global-mean warming. For the 2050s, the 90% C.I. for warming rate is 0.16–0.65°C/decade (compared with a rate of about 0.2°C/decade over the past three decades). There is a ‘natural’ (i.e., occurring in the absence of climate mitigation policies) slowdown in the warming rate after this, with the 90% C.I. for the 2090s being 0.02–0.58°C/decade. There is even a small probability (about 3%) that global warming may cease by the 2090s, corresponding to scenarios where population growth stops and global society focuses on sustainable development.

Policy scenarios.

The UNFCCC provides a basis for policies to mitigate climate change in Article 2, which states that our objective should be “…stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system”. Initial work on concentration stabilization focused on CO₂. Economically sensible stabilization pathways were developed by Wigley, Richels and Edmonds (the WRE profiles; Wigley et al., 1996) stabilizing at levels from 350ppm to 750ppm. For targets of 550ppm and above, emissions initially increased, but then were required to decline rapidly to levels well below current emissions in the 22nd century (corresponding to a rapid transition away from a dependence on fossil fuels for energy and transportation). As noted above, because of inertia in the climate system, even if we stabilize CO₂ concentration at 450ppm, considerable warming will occur in the future. Probabilistic results for the reduction in warming will be given. The situation is somewhat more dire for sea level rise: rises of 70cm and 80cm by 2400 occur for stabilization levels of 450ppm and 550ppm (using central parameter values for the climate and ice melt models).

There are three key policy questions that arise from Article 2: what should the CO₂ stabilization target be, what pathway should we take towards this target, and what is the role of non-CO₂ gases? The first question rests in part on what is meant by ‘dangerous interference’ with the climate system. This issue can be addressed probabilistically (Wigley, 2004). An analysis of this kind leads to the result that, in the absence of adaptation and/or policies to limit the emissions of non-CO₂ gases, there is a 17% chance that the stabilization target should be less than the present CO₂ level (viz. about 370ppm) – corresponding to a low value for the dangerous interference threshold and a high value for the climate sensitivity. Conversely, a high dangerous interference level and a low climate sensitivity would allow targets as high as 1000ppm. There are, however, other reasons why we should eschew such high targets – 1000ppm, for example, would lower ocean pH by about 0.5, almost certainly leading to severe consequences for ocean ecosystems.

These results point to a key role for non-CO₂ gases in limiting future climate change. Realistically (and in accord with the Kyoto Protocol), we should not focus on CO₂ alone. Indeed, a multi-gas emissions reduction strategy is likely to be far more cost-effective. I will show results for cost-optimized, multi-gas scenarios developed in conjunction with Richels and Edmonds using the Manne-Richels energy-economics model, MERGE. Reducing CH₄ and N₂O emissions in parallel with reductions in CO₂ emissions (through changes in climate feedbacks on the carbon cycle) leads to larger allowable CO₂ emissions for any given concentration pathway. In addition, for central climate model parameter values (including a climate sensitivity of 2.6°C equilibrium warming for 2xCO₂), the asymptotic warming is reduced by about 1°C, and future sea level rise is reduced, by 2400, by some 15cm.
References:

