Adapting to climate change

Legislating for the present on the basis of predictions for the future can never be other than a dicey business. The suggestion by a British member of parliament in the nineteenth century that London would be waste-high in horse excrement by the 1950s could have been seen as a call for crippling taxes on Hansom cabs, pushing cabbies out of trade while still leaving us choking on exhaust fumes. ***So should we now be legislating against those exhaust fumes, in fear that by the end of the next century the world will be a flood- and storm-prone hothouse?***

This was one of the key issues highlighted by the Kyoto convention on climate change in 1997. It is all very well to set targets for emissions reductions on the basis of climate models projected over the next century (and then in all probability to fall short of attaining them anyway), but what of the costs of fierce constraints to today's populations, particularly those who live within fragile economies?

Yet clearly we have to do something. There seems to be no serious doubt now that global warming, induced by emission of greenhouse gases through human activity, is upon us. The global average temperature has risen by around half a degree Celsius during the twentieth century, and is predicted to increase by a further 1.0–3.5 °C by 2100. Over the same periods, the seas have risen by 10–25 cm and we can expect almost a metre more at the upper limit. Storms and drought may or may not get more common, but their distribution will probably alter. Massive famine and flooding cannot be ruled out.

As it happens, the Kyoto targets may make very little impact on all of this, but the basic question remains: how can we plan for social change on timescales over which forecasts of enabling technologies become unreliable? One approach that has been advocated is to formulate policy based on assessments of human and social impacts rather than in terms of national emissions reduction targets — something that is harder to quantify but closer to people's concerns. Emissions are not the whole story; what about economic efforts to make societies vulnerable to climate change less so? And how far do political and industrial structures need re-engineering to make actual attainment of objectives realistic?

Climate modellers, meanwhile, are trying to incorporate some element of the social and economic contexts into their forecasts. They grapple with the question of whether it is better, given the uncertainties, to brake hard on emissions now, do nothing until later on the assumption that we will then be much more technologically capable of it (owing to enhanced energy efficiency and so forth), or something in between. Inevitably, such modelling is painfully contentious and strongly influenced by the assumptions that go into it. We are juggling with the unknown; and in the face of massive inertia and sharp political lobbying, that is a precarious occupation.

Philip Ball

The shape of the cosmos

Olaf Stapledon is the great unsung hero of twentieth-century science fiction. His stories are cast on scales of time and space so vast as to inspire nothing short of vertigo or terror. In *Star Maker*, his hero, in a 'hawk-flight of the imagination', journeys through the cosmos and eventually meets the Creator in his workshop. The Star Maker, it seems, is still perfecting his art. Our own cosmos is only provisional. Previous essays in Universe construction litter the room like trash. These essays come in all shapes and sizes, suggesting that we need not live in a great, expanding hypersphere, infinite in all directions.

Our conception of the shape and size of the Universe is based on timescales. The familiar 'light-year' is a unit based on the time it takes for a beam of light to get from A to B. But there is a reckoning that is purely geometric, or, rather, trigonometric. This is the 'parsec', short for 'parallax arcsecond', the distance at which the separation of the Earth and Sun (1 Astronomical Unit) would subtend an angle of one second of arc. A parsec is equivalent to just over three light-years.

But the dimensions of the cosmos are reckoned in megaparsecs — millions of parsecs. ***At the cosmic scale, the uncertainty over the rate at which the Universe is expanding means that time, distance and geometry are inextricably bound together:*** the Hubble flow is meted out in units of kilometres per second per megaparsec. On the very largest scales, time either loses all meaning or becomes subservient to geometry. Our understanding of time may depend on knowing the shape of the cosmos — the shape on the Star Maker's workbench.

In 2002, we may know. By then, we should have results from detailed maps of fluctuations in the cosmic microwave background (CMB) from two spacecraft: NASA's *Microwave Anisotropy Probe* and the European Space Agency's *Planck Surveyor*. The results will help constrain values for important cosmological parameters such as the density of matter in the Universe, and the Hubble constant that provides a scale to its expansion. Accurate knowledge of these parameters should, in turn, constrain ideas about the geometry of space — whether it is 'flat' or 'Euclidean', or if it has positive (that is, spherical) or negative (hyperbolic) curvature.

The results will also be able to tell us whether space is infinite in all directions, or is geometrically finite.

If it is finite, then some extremely weird things could fall out of the analysis. In a finite Universe, surveys of deep space could be pulling out multiple images of the same finite set of galaxies — like an observer in a hall of mirrors. One of those faraway galaxies could be our own, its light having circumnavigated the cosmos to reach us. Study of the CMB will be able to tell us whether space really is a hall of mirrors, and, if it is, something of the hall's architecture. The Universe could be an analogue of a simple sphere. On the other hand, it could have some more exotic shape, akin to a torus, or another of those shapes littering the Star Maker's garage floor.

Henry Gee