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BOOK REVIEW

The climate changers: Tim Flannery's 'The Weather Makers'

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Tim Flannery's book 'The Weather Makers' is the best account of climate change for a general audience that I've read. It covers the history of the subject, recent and ongoing changes, future projections, the international community's efforts to act, and what we can all do as individuals to reduce our carbon emissions. The book is not without flaws, including a number of factual errors, but these don't alter the message. 'The Weather Makers' is a well organised and beautifully written call to action. I came away from it with a renewed enthusiasm to change my own fossil-fuel consuming habits, and to continue my scientific efforts to understand climate change.

Flannery puts the recognition of Gaia, as a "shorthand for the complex system that makes life possible", at the outset of his argument. Splendid, I thought, being an unashamed enthusiast for James Lovelock's grand conception of Earth as a self-regulating system. Unfortunately, Flannery argues along the lines of 'wouldn't it be nice if Gaia were correct' rather than going thoroughly into the evidence and arguments. For this he may be forgiven, as he is at the outset of a book on a more specific topic, and he is writing for the general public. But he unwittingly provides ammunition for his critics, and sure enough, some prominent commentators in his homeland of Australia (where the book was first published) have attacked his 'Mother Earthism'. This is a pity because it allows them to distract attention from his core message; that we must act now to minimise future climate change.

Flannery asks "Does it really matter whether Gaia exists or not?" and answers "I think that it does, for it influences the very way we see our place in nature." Which is true, but then we part company as he describes it as a matter of belief rather than science: "Someone who believes in Gaia sees everything on Earth as being intimately connected to everything else, just as are organs in a body." Rightly he notes that: "In such a system, pollutants cannot simply be shunted out of sight and forgotten", but this is mixed with the misguided sentiment that "every extinction is seen as an act of self-mutilation," which makes little sense in a world where evolution by natural selection is continually creating new species and over 99% of

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the species that have ever lived are extinct. He concludes that: "As a result, a Gaian world view predisposes its adherents to sustainable ways of living," which I wholly agree with, but having arrived at such a world view through rather different and (I hope!) more scientific reasoning.

Flannery then trawls out the dubious dichotomy between a Gaian approach (presumably meaning holistic) and a reductionist one: "In our modern world, however, the reductionist world view is in the ascendant, and its adherents often see human actions in isolation." The rest of his book goes on to show how out-dated that statement is. He follows by suggesting "it is a reductionist world view that has brought the present state of climate change upon us." But surely it is our actions and their consequences that are responsible! Happily Flannery recovers by quoting John Maynard Smith's wise words regarding reductionism and holism: "It all depends on the problem you are trying to solve". In fact Flannery plumps for a pragmatic, and I think too weak, stance on Gaia (the complex system that makes life possible): "recognising all the while that it may result from chance." To which one critic responded 'that is still, at best, a superfluous hypothesis'.

This is not the place to rehearse the arguments for or against Gaia, but let me offer a new twist on one of them. As Flannery puts it "the most devastating rebuttal of the Gaia hypothesis is that it is teleological," meaning that planetary scale self-regulation must involve conscious foresight and planning on the part of organisms which, until recently, were unconscious of their effects on the planet. Lovelock answered this criticism long ago with the Daisyworld parable, which showed that self-regulation can emerge automatically from unconscious feedbacks. Yet exactly what the Earth system needs now is for *teleological feedback* to emerge. By *teleological feedback* I mean that we humans have the foresight to see how we are changing the Earth system and decide to change our actions in response.

'The Weather Makers' should make an important contribution to this new kind of feedback, because it makes the connection between our individual actions and their collective, global consequences. The book is divided into five sections and a total of thirty-five chapters, which makes for pithy and digestible reading. With his background as a biologist and impressive research, Flannery gives a broad cross-disciplinary scope to the impacts of climate change. There are footnotes to over two-hundred recent scientific papers and other primary sources throughout.

The story starts with an introduction to "The Great Aerial Ocean" known more mundanely as the atmosphere, and "The Gaseous Greenhouse" within it. There is an excellent chapter on the history of scientific understanding of the greenhouse effect, tracing the contributions of Jean Baptiste Fourier, Alfred Russell Wallace and Guy Callendar, alongside the more familiar (to me) Svante Arrhenius and Milutin Milankovich. Next a series of chapters introduce geologic time then home in on recent glacial-interglacial cycles and the Holocene. Bill Ruddiman's hypothesis (put forward in this journal) that humans have been affecting atmospheric carbon dioxide (as well as methane) for millennia gets a sympathetic airing. But Flannery anticipates recent results showing that the last time the Earth's eccentricity was at a 400 kyr minimum, there was a particularly long interglacial (Marine Isotope Stage 11) with remarkably stable CO_2. Thus human action does not need to be invoked to explain Holocene CO_2 levels. The first section of the book concludes with an entertaining introduction to fossil fuels, including a clear statement of what it means to act unsustainably: "over each year of our industrial age, humans have required several centuries' worth of ancient sunlight to keep the economy going."

Having introduced 'Gaia's Tools', the next section considers observed changes that Flannery links to the increase in atmospheric CO_2 that has occurred since the industrial revolution. First and foremost is the observed warming, given with undue precision as 0.63°C.

Reading as an Earth system scientist I found myself wishing for more critical examination of natural variability, of the quality of the studies cited, and of the other causal factors that might be at play. However, I am sure that some, if not all, of the changes cited are linked to greenhouse gas forcing.

Flannery suggests that the climate system has already passed through two "magic gates" in 1976 and 1998 both related to the El Niño Southern Oscillation. The first corresponded to a 0.6°C increase in sea-surface temperature in part of the tropical Pacific. The second was marked by the extreme 1997–1998 El Niño, the fires that raged in South East Asian forests, and a northward shift of the Jet Stream over North America. Flannery then moves from the tropics to the poles, where the most striking regional warming trends are found. Whilst the Arctic sea-ice decline is truly alarming, what is happening to the Antarctic sea-ice is less clear than Flannery portrays. The shift in the Southern Ocean ecosystem from krill to salps is striking but I remain unclear as to why it has happened. Back in the sub-tropics, the Great Barrier Reef and other coral ecosystems are not only threatened by warming but also by ocean acidification, which is directly linked to rising CO_2. Perhaps the neatest connection Flannery makes from global changes to local extinction is the example of the decline of the golden toad in the cloud forest of Costa Rica, where the misty conditions it depends on have largely disappeared since the world passed through the 1976 "magic gate".

The third section covers 'The Science of Prediction' beginning with the model worlds of future projections. Here Flannery mistakenly likens the 100 ppm rise in CO_2 and 5 °C warming from the Last Glacial Maximum to the Holocene to the 100 ppm rise in CO_2 seen since pre-industrial time, speculating that global dimming may be concealing much of a 5 °C warming signal. There are two errors here. Firstly, CO_2 is only responsible for a fraction of the glacial-interglacial temperature change, much of it being due to changes in Earth's albedo associated with the ice sheets. Secondly, radiative forcing is proportional to the logarithm of CO_2 concentration, so going from 280 to 380 ppm has less effect than going from 180 to 280 ppm. Such errors need to be corrected to avoid accusations of 'crying wolf' over climate change. That aside, there is much lucid and accurate discussion of the commitment already made to future climate change due to inertia in the climate system, and of the importance of positive feedbacks in amplifying change. The loss of mountain ecosystems is highlighted as are the challenges climate change poses to the migration of species on land, and to deep-sea creatures. Three potential 'tipping points' in the system are highlighted: collapse of the Gulf Stream (more accurately the Atlantic meridional overturning circulation), dieback of the Amazon rainforest, and large-scale destabilisation of methane hydrates. A recent workshop at the British Embassy in Berlin has extended this list considerably. The section closes by discussing Lovelock's suggestion that climate change could trigger the collapse of our civilisation.

The fourth section on 'People in Greenhouses' considers the response to climate change, beginning with lessons that can be learned from the ozone hole and the Montreal Protocol that sought to rectify it. Flannery portrays the 'Road to Kyoto' as paved with bad intentions on the part of Australia and other delegations that negotiated special concessions. He then takes the pragmatic view that at least we have some binding treaty in place. The refusal of the USA and Australia to sign is put down to a "frontier mentality" that wants to allow populations to expand and hence makes national targets harder to meet. Estimates of the costs of mitigation and of climate damages are critically weighed up. For the latter, the insurance and re-insurance industries provide a good indicator. Flannery then launches into the "cess pit" of those who have lobbied against action on climate change, doctored reports passing through the White House, and so forth. Names are named and I trust he has got a good libel lawyer. Then the narrative returns to the safer territory of possible engineering solutions for

climate change. Of these, carbon capture and storage for coal burning has been heralded as having great potential to reduce emissions, but the huge volumes of CO_2 that would need to be locked away make it seem less promising. Hydrogen powered vehicles are also given an explosive dismissal.

The dismissal of these technologies before the final section on 'The Solution' may be a little premature. Given the urgent need for action it seems prudent to keep our options open. Flannery is clear that the electricity production problem is most fundamental. Renewables are put first but with recognition of the problems of intermittency of supply associated with wind power. Lovelock's plea to consider nuclear power for the base load is considered, although some rather dubious statistics associated with the Chernobyl accident are aired, and it's unclear which side of the nuclear fence Flannery comes down on. He heralds geothermal energy for its potential, although we would surely lose valuable time waiting for a commercially viable deployment. Decarbonising ground and water transport is portrayed as a readily soluble problem, although I struggle to see a carbon-free solution for air travel. This leads into discussion of the potentially for an Orwellian 'Carbon dicatotorship' circa 2084.

Here we return to the theme of teleological feedback. Flannery portrays a future 'Earth Commission for Thermostatic Control' as an undesirable state of affairs, but one we may have to resort to if we don't act now. He also considers Arthur C. Clarke's suggestion that we should save coal to leave us the engineering option of burning it later in order to avoid the next ice age. His worst case scenario is one in which we "destroy Earth's life support systems", but that sounds to me like a tautological exaggeration – if they start to go, so do we, and with that our actions will surely be curtailed. The best case scenario is one in which we instigate teleological feedback at the individual level, by acting now to reduce our carbon emissions. Flannery closes by giving plenty of suggestions for how we can all go about that. He also reveals some of the efforts he and his family have made, including generating their own electricity. That practical commitment coupled to the phenomenal effort that has clearly gone into this book is truly inspiring. It would be hard to imagine a stronger call to action.