Science, Philosophy and Sustainability

The end of the Cartesian dream

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Paula Curvelo

On Cartesian dreams

More than half a century ago, in his book *Landmarks of Tomorrow*, Peter Drucker described his ‘tangible present’ – a period of fundamental shift in worldview – as an age of transition and overlap (Drucker 1957). According to Drucker, that was an age where the Cartesian worldview of the past three hundred years was still providing the means of expression, standards of expectations and tools of ordering, but was no longer acting effectively, and where ‘the new post-Cartesian, post-modern world’, though controlling human action and its impact on the world, was still lacking definition, vocabulary, methods and tools.

While discussing the philosophical shift from the Cartesian universe of mechanical cause to the new universe of pattern, purpose and processes, Drucker identifies the twofold contribution of Descartes to the modern world:

- first, his basic axiom about the nature of the universe and its order, a lawlike, mathematically determinate universe whose intelligibility became clearly expressed in the definition of science proposed by the Académie Française:[1] ‘the certain and evident knowledge of things by their causes’;
- second, inspired by the ‘long chains of utterly simple and easy reasonings that geometers commonly use to arrive at their most difficult demonstrations’ Descartes provided the method to make his axiom effective, that is: a ‘method that contains everything that gives certainty to the rules of arithmetic and that teaches one to follow the true order and to enumerate exactly all the circumstances of what one is seeking’ (Descartes 1988, 11–12).

Although recognising that few philosophers since Descartes have accepted his substantive claims or have followed him in his answers to the major problems of systematic philosophy, Drucker still considered that the dominant worldview of the modern West was the Cartesian worldview: ‘More than Galileo or Calvin, Hobbes, Locke or Rousseau, far more even than Newton, he determined, for three hundred years, what problems would appear important or even relevant, the scope of modern man’s vision, his basic assumptions about himself and his universe, and above all, his concept of what is rational and plausible’ (Drucker 1957, 2).

But if this is so, it is because Descartes's legacy to the modern world cannot be reduced to his basic axiom about the nature of the universe and its intelligibility, nor to the method upon which one would be able 'to establish anything firm and lasting in the sciences'. In fact, the epistemological ideals of clarity, detachment and objectivity that Descartes bequeathed to modern science can only be understood if we consider the underlying 'Cartesian anxiety' that hovers in the background, and which has spread to all areas of human inquiry and activity (Bernstein 1983). As Hannah Arendt reminds us, the two nightmares that haunt Cartesian philosophy –the possibility that all we take for reality is only a dream, and that humans may be nothing more than a plaything at the hands of an all-powerful malicious demon – became the nightmares of the whole modern age (Arendt 1958, 277, 279). The dark side of the Cartesian dream thus forces us to look at Descartes's legacy from a perspective that tends to expose the obsessive concern with the loss of certainty that became decisive for the whole development of modern thought, and which is inseparable from the all-pervasive radical doubt that forms the crux of Descartes's method.

Descartes's doubt concerning the reality of everything (*de omnibus dubitandum est),* and his attempt to conceptualise this modern doubt – the search for an Archimedean point that could serve as a foundation upon which we could ground our knowledge – has profoundly influenced our modern worldview, transforming the way we think about the universe, ourselves, Nature, God and knowledge, and determined the problems, metaphors and questions that have since then been at the centre of philosophy (Bernstein 1983; Tlumak 2007; Capra 1983). As Hannah Arendt noted, modern philosophy and thought began with the rise of the Cartesian doubt. In its radical and universal significance, the Cartesian doubt became the invisible axis around which all thinking has been centred, occupying much the same vital position as that occupied by the ancient Greek *thaumazein* (Arendt 1958) – the attitude of wondering that inaugurated the ascending development of philosophy, and which, according to Brentano, made it vigorous (Brentano 1998).[2]

From this perspective, questioning the end of the Cartesian dream is not only an attempt to articulate the reconstruction of an alternative understanding of scientific knowledge without the foundational metaphor that lies at the very basis of Cartesian philosophy, but it is also an attempt to understand how far we have come from the worldview that derived from it and from the problems, metaphors and questions that Descartes bequeathed to the modern age.

It is against this background that we propose to look at current proposals for the deliberate manipulation of the Earth's climate in order to alleviate the impacts of climate change. The assumption that geoengineering proposals can provide a privileged perspective from which to address the aforementioned questions follows from three lines of reasoning:

- First, because geoengineering seems to translate into reality the Cartesian dream of a practical philosophy by means of which we could 'render ourselves as masters and possessors of Nature', it can help us gain insight into current narratives of science and technology that propose scientific and technological innovation as the solution to our current environmental problems, and give meaning to human action within Nature.

- Second, inasmuch as climate engineering can arguably be considered as a typical scientific field that 'not only generates knowledge but also increases ignorance concerning the possible side effects of scientific innovation and their technological application' (Böschen *et al.* 2006, 294),[3] it constitutes a pertinent locus from which to investigate the far-reaching epistemic consequences of moving from the Holocene to the Anthropocene,[4] i.e. to a 'new geologic epoch' where the epistemic ideal of the certainty of scientific knowledge seems to coexist with – or have increasingly been replaced by – a new sort of *science-based ignorance*[5] (Ravetz 1990) that not only threatens our faith in sciences, but also threatens our new man-made world.
- Lastly, the efforts that have been made to address the array of ethical concerns associated with geoengineering (and which are far from being restricted to its unintended side effects[6]) offer some useful insights into the attempts that have been made to overcome the illusory dichotomies between mind and matter, facts and values, and subject and object, which lay at the very heart of Cartesian philosophy and of the worldview derived from it.

The main focus of our analysis is the Fifth Assessment Report (AR5) of the United Nations Intergovernmental Panel on Climate Change (IPCC),[7] which includes, for the first time in this report series, an assessment of geoengineering technologies. After a brief description of how geoengineering technologies are assessed in the three Working Group (WG) contributions to the AR5, we will critically examine the scientific and technical ideas underlying geoengineering proposals in order to address the three main questions of this chapter, which are:

- To what extent have we moved away from the Cartesian belief in scientific truth and the worldview derived from it?
- How have we reconstructed an alternative understanding of scientific knowledge without the foundational metaphor that lies at the very basis of Cartesian philosophy?
- Is geoengineering bringing into reality the Cartesian dream of rendering humankind the master and possessor of Nature?

The Science of Geoengineering: Geoengineering in the Fifth Assessment Report of the United Nations Intergovernmental Panel on Climate Change

In its Fourth Assessment Report (AR4), released in 2007, the IPCC stated that 'Geo-engineering options, such as ocean fertilisation to remove CO_2 directly from the atmosphere, or blocking sunlight by bringing material into the upper atmosphere, remain largely speculative and unproven, and with the risk of unknown side-effects' (IPCC 2007, 15). However, since the publication of the AR4, geoengineering has attracted increasing attention as a means to address climate change, having been 'transformed from a topic discussed largely in science fiction and esoteric scientific papers into mainstream scientific and policy debate' (Macnaghten and Szerszynski 2013, 465). The 'grossly unsuccessful' efforts to lower carbon dioxide emissions (Crutzen 2006) – a symptom of what has been described as a 'problem of political inertia' (Gardiner 2010, 286–7) – the call for greater planetary management and Earth-system control (Global Environmental Change Programmes 2001) and the tendency to favour transformational rather than incremental responses to climate change (New *et al.* 2010) are all factors that may help explain why the scepticism and suspicion with which geoengineering was greeted is now giving way to a more pragmatic and serious consideration of its latest scientific and technological breakthroughs and the challenges ahead.

The IPCC Expert Meeting on Geoengineering: The definitional issues

Against this background, in June 2011 the IPCC convened a joint Expert Meeting of WGI, WGII, and WGIII to discuss the latest scientific basis of geoengineering, its impacts and response options, and to identify key knowledge gaps for consideration by the author teams of the IPCC's Fifth Assessment Report (IPCC 2010, 2012).

The expert meeting proposed the use of a coherent framework for assessing geoengineering technologies across the three IPCC AR5 Working Groups, having identified the following preliminary set of criteria: effectiveness, feasibility, scalability, sustainability, environmental risks, cost and affordability, detection and attribution, governance challenges, ethical issues, social acceptability, and uncertainty related to all these criteria. It could then be expected that the consistent treatment of geoengineering options across the three contributions to the Fifth Assessment Report would add to a better understanding of: (i) the physical science basis of geoengineering (WGI), (ii) the impacts of geoengineering proposals on human and natural systems (WGII), and (iii) the role of geoengineering within the portfolio of response options to anthropogenic climate change (WGIII).

As stated in the meeting report, a substantial amount of time was spent discussing terminology in and around geoengineering (Boucher *et al*. 2011). Accordingly, the summary of the synthesis session not only provided the set of common definitions for the terms *Geoengineering* (Box 7.1), *Solar Radiation Management* (SRM) and *Carbon Dioxide Removal* (CDR) to be used in the Fifth Assessment Report, but also presented an illustration of the conceptual relationship between these terms and those of mitigation and adaptation[8], as used by the IPCC in its Fourth Assessment Report (see Figure 7.1).

The definition of geoengineering proposed by the Expert Meeting participants seems to take into account previous attempts to identify the key 'markers of geoengineering', which are: (i) the scale (global or continental); (ii) the intent (the deliberate nature of the action rather than a side effect of it) (Schelling 1996), and (iii) the degree to which the action is a countervailing measure (Keith 2000). However, special attention should be paid to the inclusion in this list of a new key characteristic of geoengineering methods – that is, that they 'could have substantive unintended effects that cross national boundaries'.

Box 7.1. Definition of 'Geoengineering' as proposed in the IPCC Expert Meeting on Geoengineering (Boucher *et al*. 2011) and used in the IPCC Fifth Assessment Report

'Geoengineering refers to a broad set of methods and technologies that aim to deliberately alter the climate system in order to alleviate the impacts of climate change. Most, but not all, methods seek to either (1) reduce the amount of absorbed solar energy in the climate system (Solar Radiation Management) or (2) increase net carbon sinks from the atmosphere at a scale sufficiently large to alter climate (Carbon Dioxide Removal). Scale and intent are of central importance. Two key characteristics of geoengineering methods of particular concern are that they use or affect the climate system (e.g., atmosphere, land or ocean) globally or regionally and/or could have substantive unintended effects that cross national boundaries. Geoengineering is different from weather modification and ecological engineering, but the boundary can be fuzzy.'

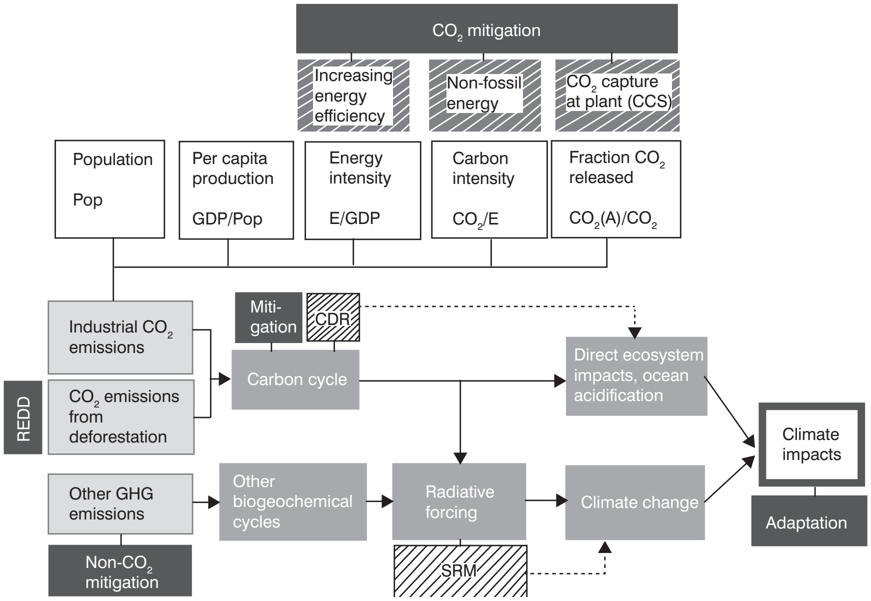

Figure 7.1 Illustration of mitigation, adaptation, solar radiation management (SRM) and carbon dioxide removal (CDR) methods in relation to the interconnected human, socio-economic and climatic systems and with respect to mitigation and adaptation. The top part of the figure represents the Kaya identity. REDD stands for Reduced Emissions from Deforestation and forest Degradation. (Source: Boucher *et al*. 2011)

In fact, as we will see next, the attempt to untangle the ambiguities associated with the term through the identification of this key characteristic of geoengineering actions generates even more obscurity in an already clouded field. This becomes particularly evident when we take into account how uncertainty surrounding geoengineering is addressed across the IPCC AR5 and how the confidence scale[9] is used to synthesise author team's judgements about the validity of findings in the field. In fact, on the rare occasions where a high or very high level of confidence is assigned to a finding concerning geoengineering, either it refers to the uncertainties about the potential of these technologies to counteract climate change or it refers to their almost certain side effects that are 'difficult if not impossible to forecast' (IPCC 2014b). The quotations in Box 7.2 are illustrative of this.

Box 7.2 What is known and unknown about the potential of geoengineering technologies to counteract climate change and about their unintended side effects.

> There is robust agreement among models and *high confidence* that the compensation between GHG warming and SRM cooling is imprecise.
>
> (IPCC 2013b, 635)

> There is only limited evidence on the potential of geoengineering by CDR or solar radiation management (SRM) to counteract climate change, and all techniques carry risks and uncertainties (*high confidence*).
>
> (IPCC 2014c, 7)

> If SRM were terminated for any reason, a rapid increase in surface temperatures (within a decade or two) to values consistent with the high GHG forcing would result (*high confidence*).
>
> (IPCC 2013b, 635)

> The knowledge base on the implementation of SRM and CDR techniques and associated risks is presently insufficient. Comparative assessments suggest that the main ocean-related geoengineering approaches are very costly and have large environmental footprints (*high confidence,* Boyd 2008; Vaughan and Lenton 2011; Russell *et al.* 2012).
>
> (Pörtner *et al.* 2014, 43)

> Depending on the level of the overshoot, overshoot scenarios typically rely on the availability and widespread deployment of BECCS and afforestation in the second half of the century. The availability and scale of these and other Carbon Dioxide Removal (CDR) technologies and methods are uncertain and CDR technologies and methods are, to varying degrees, associated with challenges and risks (*high confidence*).
>
> (IPCC 2014d, 13)

Thus, there seems to be a clear inconsistency between the definition of geoengineering presented in the IPCC AR5 and the main findings presented by the three WG. Would it make sense to review the definition of geoengineering accordingly? What level of scientific credibility could be attached to geoengineering were it to be defined as *a set of technologies and methods that intend to manipulate the climate system to counteract climate change, but whose potential to achieve this goal is still imprecise and whose unintended side effects of large scale are difficult if not impossible to forecast?*

Moreover, the option to use in this same definition two words with the very opposite meaning ('deliberately' and 'unintended') translates much of what has been said about the ignorance generated by science and reflects the growing awareness of the new unresolved problems that arise in the context of scientific and technological applications. But bringing these issues into the very definition of geoengineering is nevertheless surprising, particularly if we consider the scale to which those intended and unintended effects refer. What account of science and technology can be grasped from a field that defines itself as the intentional intervention in the global climate system to counteract the unintended effects of greenhouse emissions, and which may carry unintended (and unknown) large-scale side effects? And given this definition, what can be said about the research object of geoengineering? As M. Carrier and A. Nordmann have pointed out, 'on the technoscientific account, it is no longer possible even to construe objects like the hole in the ozone-layer or the cancer-mouse as natural. They have been created by humans but they constitute objects of scientific research all the same' (Carrier and Nordmann 2011, 4).

Geoengineering is here to stay: meanings across the three Working Groups contributions to the IPCC Fifth Assessment Report

As suggested by the participants of the IPCC Expert Meeting on Geoengineering, the assessment of geoengineering technologies across the three WG contributions to the IPCC AR5 is presented 'within the context of the risks and impacts of climate change and other responses to climate change, rather than in isolation' (IPCC 2012, 4). Accordingly, the physical science basis of CDR and SRM is assessed in chapters 6 (Carbon and Other Biogeochemical Cycles) and 7 (Clouds and Aerosols) of AR5 WGI report, while additional impacts of geoengineering proposals on human and natural systems are assessed in chapters 6 (Ocean Systems) and 19 (Emergent Risks and Key Vulnerabilities) of WGII contribution to AR5. The social, economic and ethical implications of geoengineering are assessed in section 3.7.7 of AR5 WGIII report. Further, section 6.9 of AR5 WGIII report discusses how the use of geoengineering methods can change the relationships between GHG emissions and radiative forcing and their potential role in the context of transformation pathways. Lastly, chapter 13 (International Cooperation: Agreements and Instruments) assesses the special case of geoengineering governance.

One of the aspects that drew special attention to the WGI contribution to the Fifth Assessment Report of the IPCC was the inclusion of the topic of geoengineering in the final paragraph of the 'Summary for Policymakers' (SPM) – perhaps one of the most-read sections of this report series.[10]

Although this paragraph seems intended to convey the alleged policy neutrality[11] of the IPCC, its very presence at the end of the Summary for Policymakers raised several concerns as to the new scientific status that geoengineering appears to have acquired, the way it was prematurely placed on the climate change agenda as a legitimate topic of debate and, thereby, the political leverage that can be exercised over geoengineering research and deployment (ETC Group 2014; Stilgoe 2014). The following quotation clearly illustrates this:

> In the scientific world, a final paragraph is often the place to put caveats and suggestions for further research. In the political world, a final paragraph is a coda, a big finish, the place for a triumphant, standing-ovation-inducing summary. The IPCC tries to straddle both worlds. The addition of the word 'geoengineering' to the most important report on climate change for six years counts as a big surprise … There is an argument that the taboo has already been broken and that, like sex education, it therefore has to be discussed. Those of us interested in geoengineering were expecting it to appear in one or two of the main reports when they are published in the coming months. To bring it up front is to give it premature legitimacy.
>
> (Stilgoe 2014)[12]

But perhaps the most interesting aspect of this paragraph is that it reflects much of the approach followed by the AR5 authors to present the key findings of the assessment of geoengineering techniques and their judgements about the validity of those findings. In fact, the (almost) absence of quantified measures of uncertainty to communicate the degree of certainty in the assessment of CDR and SRM methods and the option to assign a confidence level to speculative conditional sentences are two aspects of the geoengineering assessment in the AR5 that deserve closer attention. The emphasis on the side effects of CDR and SRM methods is also a key feature of all three WG contributions to the IPCC AR5 that deserves equal consideration. In the remaining part of this section we will focus our attention on these three aspects in order to address the key questions presented at the beginning of this chapter.

When assessing geoengineering technologies, the option to use a *quantitative likelihood scale* to describe a probabilistic estimate of the occurrence of a specific outcome is confined to CDR methods, particularly when referring to their side effects on carbon and other biogeochemical cycles, or to biogeochemical and technological limitations to their potential. An example of this can be seen in Chapter 6 of AR5 WGI report:

> The 'rebound effect' in the natural carbon cycle *is likely* to diminish the effectiveness of all the CDR methods.

> Uncertainties make it difficult to quantify how much CO_2 emissions could be offset by CDR on a human time scale, although it is *likely* that CDR would have to be deployed at large-scale for at least one century to be able to significantly reduce atmospheric CO_2. In addition, it is *virtually certain* that the removal of CO_2 by CDR will be partially offset by outgassing of CO2 from the ocean and land ecosystems.[13]

Despite the (i) low level of confidence on the effectiveness of these methods, (ii) the limited evidence on the potential for large-scale deployment of these technologies and (iii) their unpredictable (but almost certain) side effects and long-term consequences on a global scale, the Representative Concentration Pathway (RCP) scenarios,[14] used as a basis for future projections in the AR5, already include some CDR methods. In fact, long-term mitigation scenarios typically rely on the availability and widespread use of bioenergy with carbon capture and storage (BECCS) and large-scale afforestation in the second half of the century. As recognised in the WGII contribution to the AR5, the political implication of this is clear: 'increasing dependence of pathways on CDR options reduces the ability of policymakers to hedge risks freely across the mitigation technology portfolio'. But what does this tell us about the assumptions behind the different RCPs? What are the imaginaries of science and technology underlying the long-term mitigation scenarios?

Perhaps one of the most intriguing aspects of the assessment of geoengineering conducted by WGI refers to the level of confidence assigned to conditional sentences in order to communicate the degree of certainty in key findings. The following quotations are examples of this:

> Theory, model studies and observations suggest that some Solar Radiation Management (SRM) methods, if practicable, could substantially offset a global temperature rise and partially offset some other impacts of global warming, but the compensation for the climate change caused by GHGs would be imprecise (*high confidence*).
>
> (IPCC 2013b, 574)

> If SRM were terminated for any reason, a rapid increase in surface temperatures (within a decade or two) to values consistent with the high GHG forcing would result (*high confidence*).
>
> (IPCC 2013b, 635)

What can we infer from these statements? Can they be considered policy-relevant? If so, what scientific basis do they provide for policy-makers?

If we now return to our initial questions we have to conclude that, although we have long since recognised the severe limitations of the mechanistic paradigm informed by the Cartesian belief in scientific truth, our worldview is still entrenched in it. And this is so because the *alternative* understanding of scientific knowledge – the systemic paradigm that recognises that all scientific concepts and theories are limited and approximate, that science can never provide any complete and definitive understanding and that we always deal with limited and approximate knowledge (Capra and Luisi 2014) – has yet to recognise that there is no point in post-normal science problems in trying to emulate the mechanistic and reductionist views of classical physics in its control of uncertainty (Funtowicz and Ravetz 1990). This is one of the paradoxes of our time. The attempt to communicate uncertainties with the traditional language of science seems to run into a profound contradiction: how can one address what is not fully known in a scientific problem with the same (and expected?) quantitative scientific tools and concepts that are used to communicate what is known? In this attempt to understand system uncertainties and to explain the inexactness of scientific knowledge, as well as to communicate the limits of what can be known, science has primarily been using numerical language (see Sarewitz in this volume), the language of *objectivity*, namely what we have been educated to think of as the language of precision. The risk is clear: we may have been led to overestimate what we know about uncertainty and to underestimate the inexactness, unreliability and – most of all – our ignorance of it.

Moreover, the pressure of practice under which science operates today is giving rise to the emergence of new objects of research through which we gain a new understanding and control of Nature (Carrier and Nordmann 2011; Carrier 2011). As the assessment of geoengineering technologies in the IPCC AR5 demonstrates, the techno-scientific framing of climate change, although involving different ways of perceiving human's attempts to 'act into Nature', is giving meaning to human action within Nature and provides guidance for humans' domination of Nature.

The geoengineering worldview: Halfway between the Cartesian dream and the Cartesian nightmare?

In the mid-1980s, when the Earth System Sciences Committee of the NASA Advisory Council put forward a more complete and unified approach to Earth studies – Earth System Science – a new way of understanding and analysing the Earth system began to gain ground among scientific institutions around the world. Fundamental to this approach is a view of the Earth system as a related set of interacting processes operating on a wide range of spatial and temporal scales, rather than as a collection of individual components. Several factors have combined to stimulate this new approach to Earth studies and global change: the maturity of the traditional Earth science disciplines, developments in remote sensing systems and related earth observation activities, advances in conceptual and numerical models of Earth system processes, and the recognition of the growing role of human activity in global change (ESSC 1988, 1986).

A few years after NASA acknowledged the need to strengthen international cooperation for a truly worldwide study of the Earth, the 1992 Rio Declaration on Environment and Development and Agenda 21 (a comprehensive plan of action to facilitate the transition towards the goal of truly sustainable development), unanimously adopted by 178 Governments at the United Nations Conference on Environment and Development (UNCED), gave a major boost to the development of an integrated approach to sustainable development and the interdisciplinary focus of Earth system science and global change (Johnson *et al.* 1997).

The next important step towards a holistic perception of the Earth system as a whole and, on this cognitive basis, developing concepts for global environmental management was taken in 2001 with the establishment of the Earth System Science Partnership (ESSP), which brought together the four international global change research programmes: DIVERSITAS, the International Geosphere-Biosphere Programme (IGBP), the International Human Dimensions Programme (IHDP), and the World Climate Research Programme (WCRP).[15]

The orchestrated effort to integrate disciplinary knowledge, insights and understanding of parts of the Earth system within Earth system science gave rise to the idea of a 'global system of global systems science'. Seen as a 'substantive science of integration', this new system of global environmental science is today presented as the key to implementing any approach towards global sustainability (Steffen *et al.* 2004).

> The challenge of understanding a changing Earth demands not only systems science but also a *new system of science* … Human-driven changes are pushing the Earth System beyond its natural operating domain into planetary *terra incognita.* Management strategies for global sustainability are urgently required. *Earth System science is the key to implementing any approach towards good planetary management,* as it can provide critical insights into the feasibility, risks, trade-offs and timeliness of any proposed strategy.
>
> (Global Environmental Change Programmes 2011, 23–7, emphasis added)

This new way of understanding and studying the Earth system, the recognition that humanity itself has become a global geophysical force, allied with new approaches and a growing commitment to achieving successful and effective planetary stewardship, are leading to a profound reorientation of the global environmental change research agenda, thereby opening up a wide range of new practices, techniques and mechanisms for global governance (Lövbrand *et al*. 2009).

> The advent of the Anthropocene, the time interval in which human activities now rival global geophysical processes, suggests that we need to fundamentally alter our relationship with the planet we inhabit. Many approaches could be adopted, ranging from geoengineering solutions that purposefully manipulate parts of the Earth System to becoming active stewards of our own life support system.
>
> (Steffen *et al.* 2011, 739)

It is against this background that the idea of geoengineering, as a potential new tool for addressing climate change, is gaining ground. In fact, each new step in the direction of an integrated Earth System Science seems to have reinforced the plausibility of geoengineering proposals within the wide range of options 'towards good planetary management' (Steffen and Tyson 2001). As the results of our analysis suggest, the Cartesian mechanistic worldview, with its emphasis on the instrumental mastery of nature, is deeply embedded in the dominant techno-scientific framing of climate change and in the range of practices that have produced the 'coupled human and ecological system' as a 'thinkable' and and governable domain. Accordingly, the first step towards understanding why geoengineering 'migrated from marginal to mainstream science and policy making' (Scott 2012) should consist of a critical examination of the salient narratives that captured the shift in the relationship between humans and the global environment, in order to suggest the beginning of a potentially new geological epoch in which human beings appear to have become a driving force in the evolution of the planet and geoengineering starts to look acceptable in preventing the worst effects of climate change.

Final remarks

In this chapter we questioned the 'end of the Cartesian Dream' by taking into account the assessment of geoengineering solutions included in the Fifth Assessment Report of the IPCC. As the results of our analysis suggest, the Cartesian mechanistic worldview, with its emphasis on the instrumental mastery of Nature, is deeply embedded in the dominant techno-scientific framing of climate change and in the range of practices that have produced the 'coupled human and ecological system' as a 'thinkable' and governable domain. Although recent proposals to 'geoengineer' the climate can be seen as an early-twenty-first-century embodiment of the Cartesian dream of human mastery over Nature, they entail a particular way of thinking about the world, leading to different assumptions about stability, different processes that affect that stability, and different policies that are considered appropriate to achieving successful and effective planetary stewardship. This reinforces the need to unbind the geoengineering debate from the deeply embedded narratives of science, technology, and society which present technoscientific innovation as the solution to our most critical problems and as a substitute for social change. Similarly, the fundamental beliefs, both about Nature and about human beings, underlying geoengineering proposals need to be questioned if the social and ethical implications of these proposals are to be taken seriously. In fact, the fundamental issues of fairness, justice and responsibility that are deemed important in the ethical debate about geoengineering can only be considered if we move beyond the rhetoric of risk, fear, and control, which is providing the justification to embrace geoengineering proposals within a 'risk management strategy for climate change'.

Notes

1 In this respect, it is worth mentioning that this definition of science is still included in the 1762 4th edn of the *Dictionnaire de l'Académie Française* and only in the 6th edn of 1832 does science become defined by its subject matter, rather than by its method (Lee 2010).

2 With this in mind it is worth recalling what Descartes wrote about the first of the six major passions of the human soul (Descartes 1989, articles 70 and 76): 'Wonder is a sudden surprise of the soul which makes it tend to consider attentively those objects which seem to it rare and extraordinary … But it happens much more often that one wonders too much and is astonished, in perceiving things worth considering only a little or not at all, than that one wonders too little. This can entirely eradicate or pervert the use of reason. That is why, although it is good to be born with some inclination to this passion, since it disposes us to the acquisition of the sciences, we should still try afterwards to emancipate ourselves from it as much as possible …'

3 For an illuminating discussion of this topic see for instance Winter 2012; Hulme 2014; Rayner 2014..

4 Paul Crutzen and Eugene Stoermer coined the term Anthropocene to describe a new geological epoch 'in which humankind has emerged as a globally significant – and potentially intelligent – force capable of reshaping the face of the planet' (Clark *et al*. 2004, 1).

5 J. Ravetz has coined the term 'science-based ignorance' to designate 'an absence of necessary knowledge concerning systems and cycles that exist out there in the natural world, but which exist only because of human activities' (Ravetz 1990, 287).

6 Some significant contributions to the discussion of the ethical issues posed by geoengineering include: Hamilton 2011, 2013; Gardiner 2011; Betz and Cacean 2012; Hourdequin 2012; Preston 2012; Jamieson 2009, 1996; Schneider 1996.

7 As defined in the *Principles Governing IPCC Work:* 'the role of the IPCC is to assess on a comprehensive, objective, open and transparent basis the scientific, technical and socio-economic information relevant to understanding the scientific basis of risk of human-induced climate change, its potential impacts and options for adaptation and mitigation' (IPCC 2008, 1). To this end the IPCC produces periodic assessment reports that use a calibrated language to characterise the scientific understanding and associated uncertainties underlying assessment findings. For more information about the treatment of uncertainties in the IPCC Assessment Reports see: Mastrandrea *et al*. 2010, 2011.

8 In this regard it is worth mentioning that in the IPCC AR5 the definition of 'adaptation' differs in breadth and focus from that used in earlier IPCC reports (IPCC 2013a, 2014a, 2014b). In spite of the fact that the Expert Meeting 'did not address the question of whether these definitions should be updated to differentiate them better from geoengineering' (Boucher *et al.* 2011, 2), the new term of 'adaptation', as defined in the WGII AR5 Glossary, is supposed 'to reflect scientific progress'. However, the question of whether it resulted from an attempt to better differentiate conventional adaptation approaches from geoengineering proposals is not clear.

9 The AR5 relies on two metrics for communicating the degree of certainty in key findings (Mastrandrea *et al*. 2010): (i) Confidence in the validity of a finding, based on the type, amount, quality and consistency of evidence (e.g. mechanistic understanding, theory, data, models, expert judgment) and the degree of agreement. Confidence is expressed qualitatively; (ii) Quantified measures of uncertainty in a finding expressed probabilistically (based on statistical analysis of observations or model results, or expert judgement).

10 Reference to geoengineering in the last paragraph of the Summary for Policymakers (SPM) of the Working Group I contribution to the IPCC Fifth Assessment Report (WGI AR5): 'Methods that aim to deliberately alter the climate

system to counter climate change, termed geoengineering, have been proposed. Limited evidence precludes a comprehensive quantitative assessment of both Solar Radiation Management (SRM) and Carbon Dioxide Removal (CDR) and their impact on the climate system. CDR methods have biogeochemical and technological limitations to their potential on a global scale. There is insufficient knowledge to quantify how much CO_2 emissions could be partially offset by CDR on a century timescale. Modelling indicates that SRM methods, if realisable, have the potential to substantially offset a global temperature rise, but they would also modify the global water cycle, and would not reduce ocean acidification. If SRM were terminated for any reason, there is *high confidence* that global surface temperatures would rise very rapidly to values consistent with the greenhouse gas forcing. CDR and SRM methods carry side effects and long-term consequences on a global scale' (IPCC 2013c, 29).

11 The term 'policy neutrality' is used here to refer to the *Principles Governing IPCC Work*, which states that 'IPCC reports should be neutral with respect to policy' (IPCC 2008, 1).

12 Excerpt of the post 'Why has geoengineering been legitimised by the IPCC?' published on the Political Science blog hosted by the *Guardian*.

13 In the AR5, the following terms have been used to indicate the assessed likelihood of an outcome or a result: virtually certain 99–100% probability, very likely 90–100%, likely 66–100%, about as likely as not 33–66%, unlikely 0–33%, very unlikely 0–10%, exceptionally unlikely 0–1%.

14 Four Representative Concentration Pathway (RCP) scenarios produced from Integrated Assessment Models (IAMs) were used in the Fifth Assessment Report of IPCC as a basis for the climate predictions and projections presented by WG1 (AR5 WG1, chapters 11 to 14). These four RCPs are identified by their approximate total radiative forcing in year 2100 relative to 1750: 2.6 W m^{-2} for RCP2.6, 4.5 W m^{-2} for RCP4.5, 6.0 W m^{-2} for RCP6.0, and 8.5 W m^{-2} for RCP8.5. The RCPs with lower radiative forcing levels already include some CDR methods: the RCP2.6 scenario achieves the negative emission rate through the use of large-scale bioenergy with carbon capture and storage (BECCS) and the RCP4.5 also assumes some use of BECCS to stabilise CO_2 concentration by 2100 and, to a lesser extent, afforestation.

15 The ESSP was launched in 2001 as a response to the Amsterdam Declaration on Global Change, which called for closer cooperation between global environmental research programmes and for greater integration across disciplines, environment and development issues, and the natural and social sciences.

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