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Geoengineering knowledge: interdisciplinarity and the shaping of climate engineering research

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Abstract. In this paper we highlight the need to attend to the structuring power of knowledge production in geoengineering research, because of the way that problem definitions are shaped by disciplinary ways of thinking and describing the world. We also draw attention to a number of problematic assumptions about how interdisciplinary research should be approached and organised in this area. We first look at the logic of 'subordination', in which certain disciplines are given the task of problem definition and others—typically the social sciences—are allocated the task of filling in gaps within that given frame. We then examine the more fundamental 'integrative imaginary' which, we argue, mistakenly assumes that disciplines can be combined in a straightforward way to reveal different aspects of the same underlying world. We conclude by proposing a more reflexive imaginary for interdisciplinarity, one that challenges the idea of integration and subordination, that promotes and benefits from the multiplicity and heterogeneity of ways of seeing that different disciplines offer, and that can thereby contribute to greater 'epistemological responsibility' in geoengineering research.

Keywords: geoengineering, climate, integrated assessment, transparency, interdisciplinarity, knowledge, science, reflexivity

Introduction

Geoengineering—usually defined as the intentional, large-scale manipulation of climate processes to offset the effects of anthropogenic climate change—brings together mundane technologies such as sulphate particles, mirrors, and olivine fragments with state-of-the-art supercomputers and complex mathematical models, and the science of climate processes with engineering, studies of public perceptions, and the design of governance structures. In this complex heterogeneous assemblage, issues in the management of knowledge production are crucial, since very different disciplines and 'ways of knowing' are being drawn upon and combined in different ways. A growing number of interdisciplinary research projects are seeking to provide answers to questions about geoengineering that seem to require the competences of more than one discipline.[1] Will it work? Is it affordable? Is it safe? Is it publicly acceptable? Will it undermine mitigation efforts? And so on.

But as these interdisciplinary initiatives seek answers to these questions, they are also implicitly establishing which are the important questions that need to be answered. Since at least the 1960s, the sociology and philosophy of knowledge have charted various ways in which knowledge is shaped and in turn shapes perception of the world (see, for example, Barnes, 1977; Haraway, 1988; Kuhn, 1970). Knowledge is itself a structuring force: one which organises perception, making certain things visible while hiding others (Weingart, 2000, page 38).

[1] In this paper we use the word 'interdisciplinarity' in an inclusive sense, to include all its variants such as multidisciplinarity and transdisciplinarity, partly because of the lack of consensus over the latter two terms.

And one implication of this is that problems and issues are not simply 'out there', preexisting the particular, disciplinary ways of describing the world that are used to understand them and make them tractable (Shove and Wouters, 2005; Weingart, 2010). Disciplines are not just structured inquiries that make it possible to answer questions about how the world works (Kuhn, 1970); they are also central factors in the very formation of the questions themselves, the process of 'problem definition'. So while disciplines may always be necessary for certain kinds of patient, sustained knowledge production, the question of which disciplinary problem definition is 'better' requires an examination of the consequences of adopting different disciplinary problem-framings, and so cannot be answered from within the disciplines themselves (Lowe and Phillipson, 2006, page 169).

In this paper we argue that such crucial issues are being neglected in geoengineering research (although see Bellamy et al, 2012; Hulme, 2012). However, we also argue that current efforts to transcend the constraints of disciplinary thinking through interdisciplinarity are, at the same time, in danger of implicitly imposing their own structures of knowledge. These dynamics need to be made visible, because of the ways in which they shape how problems are framed, how resources are allocated, how research unfolds, and which future trajectories are thereby made more likely. At the moment, we suggest, geoengineering research is characterised by an 'organised epistemological irresponsibility', in which such dynamics are not being reflexively addressed and managed. In response, we sketch out a different model of interdisciplinarity for geoengineering research: one that would expose assumptions, bring out the multiplicity and incommensurability of different views and ontologies, and keep problem definitions open rather than effecting a premature synthesis. Such an approach, we argue, would be a precondition for any genuine taking of responsibility for the shaping power of knowledge production in geoengineering research.

Interdisciplinarity, policy, and geoengineering

The term 'interdisciplinarity' embraces a wide diversity of knowledge-making practices. There is no space here for a thorough discussion of classifications of different types of interdisciplinarity (see Klein, 2010); instead, we will confine ourselves to summarising some of the dimensions along which specific examples of interdisciplinary research might vary. Firstly, there is the extent to which the constituent disciplines remain fixed in their concepts, methods, and evaluative criteria, or are open to being transformed by their encounter with one another. Secondly, there is the narrow–broad dimension, which concerns whether the constituent disciplines are closely related (for example, physics and chemistry) or distant (such as geology and theology), or even whether lay actors are included. Thirdly, there is the dimension of integration—the extent to which a new shared set of methods and concepts comes to be used by all the collaborators.

In science policy circles, it has become something of a commonplace to advocate interdisciplinarity as an answer to various perceived problems in knowledge production (Barry et al, 2008; Lowe and Phillipson, 2006); however, crucial distinctions such as those above are not always taken into consideration. The key idea seems to be that contemporary problems are too complex to be tractable from disciplinary silos; interdisciplinarity, it is argued, can transcend the partial vision of the disciplines and offer more productive framings for complex research problems (Griffin et al, 2006; Klein, 2004; Tait and Lyall, 2001). However, as we shall suggest below, the specific ways that disciplines are brought together in interdisciplinary projects can have a powerful effect on the way in which problems are framed, and therefore on what are seen as robust solutions to those problems.

In the case of geoengineering, interesting patterns of interdisciplinarity are emerging. Scientometric studies suggest that collaboration between scientists in geoengineering has been largely confined to scientists in closely related disciplines working on particular technologies, such as free-air carbon capture, or solar radiation management, with little cross-citation and collaboration between these clusters (Belter and Seidel, 2013). Any interdisciplinarity has tended to be what Klein (2010) calls 'composite' (separate disciplines focusing on a common problem) and 'narrow' (involving disciplines with broadly compatible paradigms). However, a series of policy documents have advocated interdisciplinarity of a much broader variety, involving the integration of the technical and the social, transparency and accountability, ethics and governance, and engagement with nonscientists (see, for example, Bipartisan Policy Centre Task Force on Climate Remediation Research, 2011; Gordon et al, 2010, pages 12, 32; Rayner et al, 2010; Royal Society, 2009).

These general principles have been carried through into a number of currently ongoing, publicly funded research projects on geoengineering. In the UK, for example, the project IAGP (Integrated Assessment of Geoengineering Proposals), funded by the Engineering and Physical Sciences Research Council and Natural Environment Research Council, combines climate modelling with engagement with nonscientists, while CGG (Climate Geoengineering Governance), funded by the Economic and Social Research Council and the Arts and Humanities Research Council, explores the ethical, legal, social, and geopolitical implications of geoengineering. In France the National Agency for Research's two-year scoping project REAGIR (Reflections on Environmental Geoengineering) includes scientific and technical as well as socioeconomic and ethical dimensions. The six-year, interdisciplinary priority programme of the German Research Foundation, "Climate engineering: risks, challenges and opportunities", has the goal for its eight subprojects of creating a scientific basis for a "comprehensive assessment" of different types of geoengineering, from "scientific, environmental, economic, social, political, ethical, and communicative perspectives". The EU-funded project EuTRACE (European Trans-disciplinary Assessment of Climate Engineering) describes itself as adopting a 'transdisciplinary' approach to evaluating geoengineering proposals. In the USA "The Ethics of Geoengineering", funded by the National Science Foundation, combines philosophy, social science, and public engagement.

Such developments are to be welcomed: involving a range of disciplines and approaches, taking into account public views and being transparent and open about research activity are all highly desirable characteristics for research in an area which would constitute a 'real-world experiment' at a global scale. However, what has not been given sufficient attention is the way in which the specific understandings of interdisciplinarity and transparency being mobilised in geoengineering research might themselves impose particular framings on problems, further obscure disciplinary assumptions, and thereby limit learning and epistemological responsibility.

We must therefore add a fourth dimension of interdisciplinarity to the three considered above, one that we might call the 'reflexivity dimension'—*the extent to which the dynamics of knowledge formation in interdisciplinary collaborations are made explicit, and potential blind-spots avoided*. In the following two sections we draw on some initial findings from research on interdisciplinarity in geoengineering to illustrate the importance of attending to such dynamics.

The subordination of the social

One commonly criticised syndrome within interdisciplinary research—captured variously by the terms 'multidisciplinarity', or 'auxiliary' or 'bridge-building' interdisciplinarity (Klein, 2010)—involves the bringing together of disciplines in a way which nevertheless leaves them unaltered. Within this category sits a more specific 'subordination–service' mode of interdisciplinarity, in which the problem framing of one discipline dominates, and other disciplines are used to provide information within these terms (Barry et al, 2008, page 29; Demeritt, 2009, page 7). In environmental research it is often the social sciences which are made to take up this subordinate role, providing a way to add 'social factors' into problem definitions from the natural and engineering sciences, but without fundamentally challenging these framings (Wynne, 1994).

The dominance of natural scientific communities in shaping environmental discourse is evident in the case of geoengineering. For example, although the 2009 Royal Society report calls for more social and ethical research, it takes the scientific domain for granted. For example, in the report's influential figure 5.1, which presents an initial synoptic assessment of different geoengineering technologies using both technical and nontechnical criteria, the notion of 'effectiveness' is used for one of the diagram's two axes, and is central to the conclusions drawn about the 'desirability' of different techniques (Royal Society, 2009, page 49). Yet the kind of questions that the social sciences could contribute, such as "effectiveness for what?", "effectiveness for whom?", are not asked. Effectiveness is preframed in a way that implicitly defines a social context (Gardiner, 2010; Hulme, 2012), one in which the highest aim is to rapidly cool the planet. Such preframings are not without effect: for example, if other criteria such as 'potential unintended effects' had been taken into account in the concept of 'effectiveness', stratospheric aerosols would have probably not been ranked so highly.

The subordinate role for the social sciences has also often been assumed in many subsequent research projects. It is typically only once the impacts and risks have been defined by a physical science frame that the social sciences are invited to play a role. The Solar Radiation Management Governance Initiative report, for example, used a physical science framing to deem computer simulations "non-hazardous research", in contrast to research taking place outside the laboratory (SRMGI, 2011, page 45). However, from a social science or humanities point of view, computer-based research might well be deemed hazardous, since it could well involve key processes of world construction which will influence future pathways of action, by shaping what is seen as possible to do, safe to do, or desirable to do. The case of the test bed for the project SPICE (Stratospheric Particle Injection for Climate Engineering), in which controversial plans to test a delivery system for stratospheric aerosols were eventually abandoned (Brumfiel, 2011; Cressey, 2012; Macnaghten and Owen, 2011) is another example in which a physical science model was only later complemented with 'social intelligence' (Parkhill and Pidgeon, 2011).

In current geoengineering research, the dominant understanding of the role of the social sciences and humanities seems to be to ensure that governance processes are informed by public concerns and values (for example, Corner et al, 2012), rather than to open up the processes by which scientific knowledge is produced. This dynamic is clear in calls for 'transparency' in geoengineering research (eg, House of Lords Science and Technology Select Committee, 2000; Rayner et al, 2010; Royal Society, 2009), which take place against the background of a wider interest in transparency as a necessary feature of mode 2 knowledge production (Barry et al, 2008; Lowe and Phillipson, 2006). Yet transparency, interpreted as the making visible of processes and results, has its limits; the hidden normative assumptions of geoengineering research discussed by Bellamy et al (2012) are rarely opened up for discussion in such procedures, and neither are issues of epistemological power such as the concentration of climate modelling in a few institutions.

One of the means employed to increase transparency is public engagement. In the NERC-funded *Experiment Earth* public dialogues, (IPSOS-Mori, 2010), it was reported that the public had "little awareness of the scientific process", so were given an opportunity "to discuss with scientists how research works" at the final workshop—although they seemed wary about making decisions about whether to support a new area of science (Hurrel, 2011). Yet how much difference could a dialogue between public and scientists make in this context? What is the point of transparency if the processes that shape science remain neither visible nor open to intervention? As Liverman points out, although programmes such as the Global

Climate Research Programme (GCRP) involve the social sciences, many of the issues are already prematurely framed (1999, page 115). In this context, public scrutiny can indeed have the effect of pushing science to an *even tighter* problem definition and premature closure. In such a context it is imperative to think about the role that the social sciences and humanities can play in broadening the kinds of questions being asked.

The integrative imaginary

One key idea in the kind of interdisciplinarity practised in geoengineering research is that of the 'integration' of different kinds of knowledge. This manifests what Barry et al call an "integrative or synthesis model of interdisciplinarity, in which the interdisciplinary field is conceived in terms of the integration of two or more 'antecedent disciplines'" (2008, page 28). In practice, such integrative interdisciplinarity might simply involve the integration of knowledge from different disciplines; but in its fullest form it could involve the integration of ways of thinking from different disciplines into a new field with a shared paradigm, as happened, for example, with women's studies, molecular biology, and Earth system science.

This sort of 'integrative imaginary' is prominent in the literature on interdisciplinarity, and has become particularly influential in environmental research. It provides the background to science-funding agencies now looking to support large, multicomponent research programmes like the UK RELU programme (Rural Economy and Land Use) that bring together different kinds of specialist expertise to address pressing problems such as sustainability. It also informs the idea of 'integrated assessment', which is presented as a framework for combining knowledge from a wide range of disciplines in order to evaluate a problem from a synoptic perspective, often using computer models that combine physical and social data (Rotmans and Dowlatabadi, 1998, page 292).

In geoengineering research, this imaginary was strengthened by the Royal Society diagram mentioned above (2009, page 49), which has had a particular influence on the way in which interdisciplinarity is imagined in projects aimed at interdisciplinary 'integrated assessments' of geoengineering technologies. In their very conception, such initiatives are shaped by two assumptions associated with the integrative imaginary: that knowledge from different disciplines *can* be brought together in a straightforward sense; and that adding all this knowledge together will provide a more complete understanding of the problem at hand.

However, both of these assumptions can be problematised. Firstly, as Shove and Wouters point out, interdisciplinarity in this mode assumes that radically different ways of knowing can be made commensurate, neglecting "[p]otentially important subtleties in how specific disciplines interact and in how real world problems are translated and resolved into researchable questions by specialists in different fields" (2005, page 3). By neglecting exactly how empirical 'facts' are generated, unexamined scientific assumptions are taken out of their original context and reified. Secondly, this mode of interdisciplinarity assumes a rather outdated realist epistemology according to which there is "a single reality 'out there'" (Castree et al, 2009, page 9; see also Weingart, 2000, page 37). By taking this realist idea for granted, geoengineering research neglects the way in which different disciplinary perspectives are implicated in the production of the very phenomena that they study.

Doing interdisciplinary geoengineering research otherwise

We have argued in this paper that interdisciplinarity in geoengineering is taking particular patterns. The 'narrow' interdisciplinarity characteristic of the research on particular geo-engineering techniques is increasingly being complemented by a growing range of projects pursuing a 'broad' interdisciplinarity that seeks to combine the natural and social sciences, and the views of the public. But interdisciplinary research in the field of geoengineering tends to assume a structure of knowledge in which different disciplinary contributions can be combined unproblematically, and in which the physical sciences define the problem, and the social sciences, if present at all, are given a determinate, proscribed role. This kind of interdisciplinarity, we have suggested, remains unreflective about the way in which disciplines construct objects of study, how ontological and epistemological legacies that are attached to specific disciplines are carried, often invisibly, into interdisciplinary settings, and how interdisciplinarity itself can also subtly shape knowledge production. This kind of interdisciplinarity not only frames the problems investigated but also constrains the types of solutions which emerge from it. The move to interdisciplinarity can, in practice, intensify the problems of unreflexivity about unexamined assumptions and framings, and reproduce and consolidate power relations between disciplines.

If interdisciplinarity is to fulfil its full epistemological potential, processes of problem definition—and resource allocation—need to be open-ended and ongoing (Lowe and Phillipson, 2006, pages 169-70). For this to be realised, we need a different, more reflexive mode of interdisciplinarity. Barry et al (2008, page 25) describe such an alternative, an 'agonist–antagonistic' mode of interdisciplinarity that has the potential to "destabilize existing disciplines and practices leading to a reconfiguration of their boundaries, objects and problematics" (page 30). Castree et al (2009) similarly attempt to move away from the dominant symmetric understanding of environmental geography by celebrating geography's plurality and multiparadigmatic nature. Since humans and nonhumans are connected in a multiplicity of ways, they suggest, we need to theorise these associations in an asymmetrical manner, in which disciplinary contributions do not necessarily add up into a single, unified account. Demeritt (2009, page 9) similarly calls for forms of interdisciplinarity where those working within other paradigms are seen as interlocutors to be challenged, rather than simply providing inputs for analysis or as externalities to be ignored.

What we can see emerging here is a model of interdisciplinarity that involves heterogeneous methods and asymmetric contributions, underpinned by a model of the 'disunity of the sciences', epistemological pluralism (Dupré, 1993), and ontological multiplicity (eg, Mol, 2002). Implementing this more reflexive kind of interdisciplinarity could help to increase the range of natural scientific approaches in geoengineering research—for example, including more diverse approaches to modelling and involving underrepresented disciplines such as ecology in geoengineering appraisals. It could also produce greater diversity and reflexivity in *how* different disciplines and approaches are brought together. The climate computer model itself needs to be dethroned as the most desirable way of combining disciplinary knowledge, and there needs to be more openness to the idea that the clash of disciplinary perspectives can sometimes be more generative of understanding than an apparently successful attempt to harmonise them through the production of apparently commensurate data (Kwa, 2005). A more reflexive interdisciplinarity would also generate more diversity in the kind of social science and humanities research in the field, and in the role that such research plays in geoengineering appraisals. Deliberative public dialogues have succeeded in *broadening* the discussion, by expanding the elements that are seen as salient to geoengineering (Bellamy et al, 2012); but they have been less successful in *deepening* the discussion by opening up to scrutiny the production and framings of scientific knowledge—or indeed of public opinion (Felt and Fochler, 2010).

There is a need for a more concerted exploration of forms of 'ontological', 'agonistic', or 'asymmetrical' interdisciplinarity in geoengineering research, a move that would be consistent with a comportment towards climate engineering that elsewhere we have called that of the 'climate artist' (Galarraga and Szerszynski, 2012).(2) This involves recognising that the fashioning of climate, like the creation of a work of art, would be a form of world making:

(2) As opposed to a 'climate architect' or a 'climate artisan'.

a moment of historical rupture in which intentions and ways of thinking may be transformed. The climate artist has to take responsibility for this world-making power. Interdisciplinarity can potentially help facilitate such a stance by keeping problem framings open and subject to reflection, contestation, and revision; but it can also make it harder, by reifying disciplinary outputs and occluding the processes that shape the production of knowledge. Which of those two possibilities dominates future geoengineering research will determine the extent to which interdisciplinarity is a friend or foe to practices of epistemological responsibility in this highly consequential area of research.

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