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Geo-Engineering the Climate: Time for a Technology Assessment

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Introduction

The threat of anthropogenic global warming has traditionally been met with plans to reduce greenhouse gas (GHG) emissions (mitigation) and to help social and ecological systems cope with a changing climate (adaptation). There is some tension between advocacy and policy for mitigation vs. adaptation, but given a probable (though difficult to specify) "warming commitment" already extant and likely to increase before effective mitigation kicks in, greater attention is coming to adaptation (Pielke, Jr., et al., 2007). The human experience with natural hazards and other environmental problems also suggests that an increasing threat of global warming (and associated local and regional climate changes) will eventually evoke efforts to intervene physically in the climate system (Schneider, 2001), especially if the more extreme scenarios begin to look likely or to become manifest (Travis, in review). A flurry of proposals, conferences, and articles on "geo-engineering" (e.g., Crutzen, 2006; Wigley, 2006) reveals that the prevention response has gained salience, at least as a topic for discussion and rudimentary analysis (Cotton, 2008). The discussions evince a mixture of, on the one hand, enthusiasm for the great potential for fixing the problem and, on the other hand, great caution in the face of myriad unknowns. Many commentators suggest that the cure might be worse than the disease, that serious attention to geo-engineering solutions might even worsen the problem by reducing our commitment to mitigation, and that even analyzing engineering solutions puts us on a "slippery slope" to relying on them instead of mitigation (e.g., Robock, in press). In this vein, the thinking goes, serious attention to climate cooling schemes might invoke a paradox that natural hazards researchers call the "levee effect" (i.e., that dams and levees encourage flood zone development, thus exacerbating future losses when inevitable failures occur). I'll take up this "moral hazard" argument below.

This essay examines some of the human dimensions of weather and climate geo-engineering (WCGE), in a rough attempt to identify some of the elements likely to comprise a WCGE technology assessment.

The Broad Range of Weather and Climate Geo-Engineering

Humans have intervened in earth systems throughout their history on the planet Costanza et al., 2007). Our purposeful efforts have been guided by an enduring criterion, really a universal theory of intervention: we seek the "levers" that yield the greatest results for the least effort (our deployment of nitrogen to increase crop yields is surely the most astoundingly effective of such levers). Of course, we have also stumbled inadvertently upon other levers (e.g., the radiative effectiveness of greenhouse gases).

Weather and climate geo-engineering (WCGE) is also based on finding the least-cost levers to manipulate sub-sets of earth the system, and a wide spectrum of WCGE tools and approaches are in use today. Over centuries both scientific and pseudo-scientific methods have been applied, some effectively, most not (Flemming, 2007). Since WCGE to reduce global warming will inevitably evoke a wide ranging technology assessment, what could be the most important technology assessment in human history, examining the wide range of modification technologies tried in the past will tell us something about the nature of the debate before us.

Perhaps the most common assessment of the human dimensions of weather and climate modification is surprise, even awe, at human credulity. An outsized sense of control over nature, and a willingness to accept poorly-supported claims of effectiveness have marked the whole history (Steinberg, 2000; Flemming, 2007, concludes: "…if there is one lesson from the long history of efforts to modify the weather and climate, it is that neither -commonsense criticism nor flops deter geoengineers." p. x.).[1] Governments and learned societies seem as subject to this a lay people: the USDA supported the notion that 'rain follows the plow" in their zeal to spread agriculture onto the Great Plains, and the American Association for the Advancement of Science lent credence to the theory that planting trees on the Plains would permanently ameliorate the region's (unfortunate) semi-arid climate. By the mid-20th century, schemes had gone well beyond rainmaking, to continent scale engineering plans, including a Soviet scheme to divert Arctic Slope freshwater runoff, thus increasing the salinity and decreasing the ice cover of the Arctic Ocean (Kellogg and Schneider, 1974), a plan eerily similar to mechanisms that some scientists now fear could affect the thermohaline circulation.

Recent and contemporary weather modification programs are all more limited in scope, and rest on a mixture of slender, but encouraging, scientific substantiation (Committee on the Status and Future Directions in U.S Weather Modification Research and Operations, 2003) and sincere, but also wishful, thinking (Flemming, 2007). A peculiar sort of cost/benefit analysis often adheres to, and furthers cloud seeding: application is often relatively cheap compared to the benefits even of a signal (effect) that resides within, or just barely rises above, the noise of weather variability. This applies to everything from slight snow pack augmentation to the logic for 1960s hurricane seeding, and is partly because, as Cotton (2008) argues, people, including often politicians, demand some sort of action when resources are threatened. Nevertheless, cloud seeing is conducted on a routine basis in many places in the U.S. and around the world, without discernible negative effects or significant social opposition (Cotton and Pielke, 1995; Garstang et al., 2005).

Realized global warming is likely to call forth a great deal more local and regional weather modification, including especially precipitation enhancement and hurricane modification (NOAA/DHS, 2008). It also works out that, despite the initial attention to

[1] I ran into this myself while installing raingages in the sugarcane fields of south Florida: more than one farmer told me that gages near the flooded fields would receive more rainfall, that they were able to shift rainfall patterns via their water management.

global schemes like stratospheric aerosol injection, many anti-global warming schemes are based on more conventional weather modification techniques (Cotton, 2008), including seeding to change the albedo of naturally extensive cloud systems like oceanic strato-cumulus or high level cirrus (ships already enhance oceanic clouds from their stack effluent and jets make cirrus clouds via contrails). Given a spectrum of options, including those already in the arsenal of weather modification, potential exists for field trials that carry little risk of negative climate interference.

Some Pros and Cons

Robock (in press) lays out "20 reasons why geongineering may be a bad idea." He includes obvious negatives like unintended consequences and the potential dampened enthusiasm for mitigation, but also more discerning ideas, like weaponization, accidents, and the potential for over-correction. And certainly a cautious attitude will flavor the coming technology assessment: WCGE schemes will be viewed as dangerous unless proven otherwise, a version of the precautionary principle that will surely make it difficult for any scheme to pass muster. But there are reasons why WCGE might be a good idea, and reasons why, in the coming technology assessment, we should pay some attention to the possibility of rejecting an effective and benign scheme, should one appear on the list. While not rejecting Robock's 20 negatives, I'll offer 5 positives:

1. Any serious WCGE proposal will have to pass muster for effectiveness and lack of negative impacts first through rigorous modeling simulation. The necessary modeling "bake off" will surely bring more effort and resources to bear on weather and climate modeling, an effort needed for the whole global change problem.
2. Careful laboratory and field testing of WCGE efforts will provide more empirical insights into how earth systems work, insight that cannot be gained via modeling or paleo-studies alone. These insights will be just where we need them: in cloud processes, radiative effects and feedbacks.
3. The WCGE technology assessment, which I believe will be made compulsory by the global community, will further our understanding of the human dimensions of earth systems.
4. WCGE efforts, if shown effective, may be able to reduce the near-term effects of climate change, shaving off at least some magnitude of losses and impacts, and providing resources and time for mitigation and adaptation. In this way they appear as an aid to human development in a dangerous time, not unlike the many other levers humans have deployed to manage natural resources.
5. WCGE may be needed if global warming is worse, and/or occurs faster and in more abrupt manner, than currently projected. In this way WCGE schemes act more like insurance than as an excuse to weaken mitigation efforts.

The moral hazard argument is difficult to refute, at least party because its adherents have not demonstrated its real-world effects in analog cases. Insurance programs seem more affected by adverse selection than by moral hazard, and the question of whether disaster relief encourages risky behavior has not been settled after years of debate among hazards researchers, suggesting to me that the effect is not very strong. Mileti (1999) concludes that expectations of relief do not necessarily encourage hazard zone occupance, but insurance might. The leading scholar of hazards insurance, Howard Kunreuther, who has argued that insurance theory can and does lessen the potential for moral hazard, concluded after Hurricane Katrina that expectations of government aid do indeed reduce adoption of both pre-hazard mitigation and of insurance (Kunreuther, 2006). Of course, insurance companies have a hook to enforce mitigation (e.g., discounts for risk reduction behavior) and relief rarely compensates for all losses, so the logical homeowner, for instance, does not use either as an excuse to ignore risks. Perhaps outrage that our energy use has us shooting thousands of artillery rounds into the stratosphere and/or whitening the sky with artificial clouds would actually intensify the urgency of mitigation.

Assessing the Options

Unless current and projected global warming reverses, weather and climate intervention schemes will be put forward with increasing enthusiasm, and some schemes, starting with the smallest scale, least intrusive ones, will almost certainly be tested in the field. While attention will fall on proposals to change the earth's radiation balance, being the obvious antidote to GHG-induced climate warming, there is some value in casting a wider net, to assess a fuller spectrum of purposeful and inadvertent human interventions in weather and climate so as to begin to illuminate the needed dimensions of an important and needed technology assessment.

One early step in the inescapable technology assessment for WCGE should be to look back at previous assessments, a wide range of which were conducted, for example, by the U.S. Office of Technology Assessment during its 23 years of operation up to 1995 (some 750 separate assessments (!) which are available on line, at: http://www.princeton.edu/~ota/ns20/pubs_f.html). Other major assessments were conducted for the super sonic transport, nuclear power, and hazardous wastes.

Though there is no standardized assessment template, typical ones include a look at: feasibility, cost/benefit, risks, social and environmental impacts (positive and negative), institutional frameworks, and ethical dimensions. The big news in TAs comes when a thoughtful, hard look (at everything from the space program to sanitation systems for arctic slope villages, in OTA's case book), reveals a subtle problem, hidden flaw, or fundamental contraction that calls into question the effectives of the technology. But many predict positive outcomes. The important overarching goal of TA is a careful, multidisciplinary look into the future of the technology, and at least a start at identifying and addressing issues like safety, oversight, liability, compensation, etc.

One solid lesson from hazards and technology studies is to avoid getting trapped in one approach too early in the assessment and development process. This may already affect the range of options discussed in geo-engineering, and attention to the full range of weather and climate modification knowledge and potentials allows us to call on past experience, to anticipate objections, pit-falls, and perhaps to create an assessment scheme that strikes a balance between the probability of accepting bad, and rejecting good, WCGE ideas.

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