

Geoengineering: What, how, and for whom?

I have been thinking about geoengineering for climate modification since I worked on the committee that produced the 1992 National Academies report, *Policy Implications of Greenhouse Warming*. Over the years, and increasingly now, I have been puzzled by the scientific community's attitudes toward the issue; those puzzles were raised again by Barbara Goss Levi's story (PHYSICS TODAY, August 2008, page 26).

It has been customary to discuss geoengineering without offering an explicit definition. I propose the following one: Geoengineering is purposeful action intended to manipulate the environment on a very large—especially global—scale. Geoengineering is, presumably, undertaken to reverse or reduce impacts of human actions.

Decreasing human emissions of carbon dioxide and other greenhouse gases is a good idea for many reasons, including climate modification; yet it is not clear to me why manipulating the CO₂ content of the atmosphere is not considered geoengineering. If, using the above definition but narrowing it to the case under consideration, geoengineering includes purposeful manipulation of physical, chemical, and biological variables on the global scale for the purpose of changing global climate, then manipulation of carbon dioxide concentrations fits the definition as well as do, for example, manipulating atmospheric aerosol content to control albedo or manipulating the ocean's iron content to increase the long-term oceanic storage of carbon.

Exclusion of carbon dioxide manipulation from geoengineering has led to

a double standard in considering possible negative consequences. There is legitimate concern about side effects of particulate manipulation and the like, but I have not heard much worrying about manipulating carbon dioxide.

In a highly nonlinear feedback-controlled system like global climate, we would expect complex hysteresis effects: Decreasing a control variable such as greenhouse gas will not necessarily lead the climate back along some path like the one it followed when the control variable was increased. The end state of control-variable manipulation may not at all resemble the original state before the control variable was increased, nor will it necessarily be a state we want to be in. I have heard of no concern about those possibilities, which might be rate dependent, involve transient behavior not to our liking, or lead us through bifurcations into unexpected states.

It seems to me we need to be concerned about possible not-so-benign effects of decreasing carbon dioxide and other greenhouse gases before we grab the control knob and turn it down. I hope someone is at least exercising suitable climate models, if relevant ones exist, to examine possible end states, paths to them, and transient effects of carbon dioxide geoengineering.

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The Issues and Events report on the viability of geoengineering to counter global warming did not address the ethical issue. I use the following fable to illustrate the point.

Once upon a time in an idyllic country, near a small town and a farming community, a rope hung out of the sky. One pull on the rope changed the weather from fine and sunny to cloudy and rainy, and the next pull changed it back. For many years the people cooperated; the farmers used the rains to help grow crops, and the townspeople enjoyed the sunny periods. But there came a time when the townspeople protested the rain and wanted more sunshine. The farmers were concerned about their crops. And so arguments broke out, with a person from the town pulling on the

rope, followed quickly by a farmer pulling it again, and they pulled and pulled and . . . broke the rope.

Given that the climate is changing because of inadvertent consequences of human activities, the question arises as to whether efforts should be made to deliberately change climate to counteract the warming. Aside from the wisdom and ability to do such a thing economically, the more basic question is the ethical one of who controls the rope. Who makes the decision on behalf of all humanity and other residents of planet Earth to change the climate deliberately?

Climate change is not necessarily bad. The climate has always varied to some degree, and changes have occurred over decades and millennia. Humans and other creatures have adapted to the changes or perished; it is a part of evolution. Changes projected with increased greenhouse gases in the atmosphere may have some aspects that could be regarded as bad; increased heat waves and wildfires in summer, increased and more intense droughts, heavier rains and risk of flooding, stronger storms, decreases in air quality, and increases in bugs and disease are all likely threats. But in some areas, climates improve, high-latitude continents become more equable, growing seasons are longer, and so on. There are winners and losers. And it is possible to adapt to such changes—at least if the changes occur slowly enough. In other words, key issues are the rate and duration of change, perhaps more so than the nature of the new climate. In that sense, it is the disruptive part of climate change that might be argued as being bad.

Given that climate change is not universally condemned, how can anyone justify deliberately acting to change the climate to benefit any particular group, perhaps even a majority? The ethical questions associated with climate manipulation loom so large that some forms of geoengineering are simply unacceptable. The forms that are acceptable include those that reduce emissions and mitigate the rates of change or reduce the amount of carbon dioxide in the atmosphere. Forms that propose to block sunlight in some fashion, per-

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haps to emulate a volcanic eruption, would change the hydrological cycle and weather patterns in ways that would be simply unacceptable, even if they were doable. The cost and viability of any such proposals are other major issues, but in my view, they are overwhelmed by the ethical considerations.

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University of Tsukuba defends professor's dismissal

Administrators at the University of Tsukuba have read the letter from 11 physicists who criticized the university's disciplinary action against Teruji Cho (PHYSICS TODAY, December 2008, page 10). We are concerned that the writers did so without a full grasp of the incident and the procedure followed by the university. The university's website has posted the official investigation report in Japanese (http://www.tsukuba.ac.jp/public/press/080306press_4.pdf) and an abridged English translation (http://www.tsukuba.ac.jp/english/public/pressrelease/p_report/report_d.pdf).

The University of Tsukuba has an established system of handling incidents of research-related misconduct under its Scientific Ethics and Research Conduct Committee. SERCC sets up an investigation committee that examines the details of the case and reports its findings to SERCC. If SERCC concludes that misconduct was perpetrated, the disciplinary committee of the university's Education and Research Council determines the disciplinary measures.

For the incident involving Cho and three assistant professors, the procedure was strictly followed. The investigation committee, whose members are listed in the online documents, included three distinguished plasma physicists from outside the university.

After a year of investigation between April 2007 and March 2008, SERCC concluded that Cho and his three coworkers falsified raw data to make two figures for their paper published in *Physical Review Letters* (PRL)¹ and that the falsification constitutes scientific misconduct. SERCC based its conclusions on an in-depth examination of documentary evidence, including e-mails and intermediate analyses, that it acquired from the students who filed the misconduct complaint and from

Ode to the Large Hadron Collider

Deep beneath the farms of France, physics takes a massive chance.
Europe's best and brightest teams focus up their narrow beams,
While gangs of dedicated geeks tighten tubes and look for leaks.
Giant magnets, so it's said, accelerate a proton thread
Until it hits the speed of light—well, maybe not exactly quite—
But anyhow, extremely fast. The speed of light is unsurpassed.

When protons have sufficient spin, they're whacked against their proton kin,
Spun from an opposing strand, swirled around from Switzerland,
All aligned with great precision, smashed together in collision.
Then, whatever fragments found, fathom matters most profound:
Like, What are mass and gravity, space and supersymmetry?
Dimensions deep and matter dark? What riddles lurk within the quark?
Is it worth the money spent on this vast experiment?
Other questions, not as thrilling, strangely garner equal billing:

What if all this, just perhaps, precipitates a mass collapse?
Could the apparatus heave a flying hadron through Geneva?
Could quantum spin and somersaults zap the gold in Zurich's vaults?
Sour the milk and spook the pigs? Just what if the hunt for Higgs
Tolls our final self-destruction or invites an alien abduction?
What would Isaac Newton think? Would he envision Earth might sink?
Humanity, prosperity, down a singularity?

For this we've waited many years to have a hadron smash,
Boldly probing new frontiers and spending piles of cash.
Scientists seem unconcerned, proudly listing all they've learned,
While their rivals gather traction in equal and opposing action.

Alas, no protons whizz around, and silent is the ring.
No hadrons thread the underground, at least until the spring.
Some free advice on this device, while disappointment lingers:
Find that glitch and throw the switch! Be sure and cross your fingers!

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Cho and coworkers. SERCC reported its conclusions to the president of the university on 4 March 2008 and advised that the authors retract the paper. The president acted on those conclusions and advice. Subsequently, the disciplinary committee determined that Cho should be dismissed from the faculty, and that action was carried out on 27 August 2008. The committee also decided that the three assistant professors be suspended from their positions for one to four months; that was put into effect on 16 October 2008.

During the investigation, the university, through SERCC and the investigation committee, took every measure to guarantee that Cho and the three coworkers had opportunities to present their views and rebuttals in written form. Those rebuttals, however, failed to convince SERCC to reverse its conclusions.

In the incident, the falsification occurred during the process of making two figures from raw data. Since access to the raw data was confined to Cho's group, uncovering such a falsification would have been extremely difficult if

students from the group had not raised the issue. Besides Cho and the suspended professors, 11 University of Tsukuba faculty members are listed as coauthors of the PRL paper. They are experts on the GAMMA-10 tandem mirror and longtime collaborators with Cho. However, even they could not detect the falsification. After the investigation, 23 coauthors, including 1 of the 3 suspended assistant professors, have asked the PRL editorial office to withdraw their names from the paper.

The incident has been deeply troubling for the university, since the mirror fusion research led by Cho had been an important component of our scientific activities for many years. We therefore made every effort to follow the due process of investigation and make sure our decisions were based on fact. The findings left us no choice but to take the action against Cho and three coworkers. The university's investigation was open, and the results have been made public. We invite our colleagues in the international academic community to read the reports so they can understand the reasons for our action.