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The Greenhouse Effect and the Bathtub Effect

By ANDREW C. REVKIN

The atmospheric "tub" of carbon dioxide is filling faster than it's draining.

A new paper in the Proceedings of the National Academy of Sciences, concluding that the buildup of human-generated greenhouse gases could leave a profound millenniums-long imprint on climate and sea levels, focuses on a characteristic of global warming that the public, and many policymakers, have not absorbed — at least according to John Sterman at M.I.T.

That characteristic is the "bathtub effect" behind the human-amplified greenhouse effect. Dr. Sterman, a prominent analyst of risk perception and management at the Sloan School, has devised various tools akin to flight simulators to help corporate leaders understand the nature of a variety of problems and choose among various remedies. He recently turned this approach to climate, which he says bears much more resemblance to deficit spending and the national debt than it does to 20th-century-style pollution problems like acid rain.

Basically, the atmosphere is like a bathtub with a partially opened drain. Carbon dioxide from burning fuels and forests is flowing in twice as fast as it is being absorbed by plants and the ocean, and some of those "sinks" are in fact getting saturated, it appears, meaning that the "drain" is clogging a bit. (More on "CO_2's Long Goodbye".) [UPDATE, 1/29: Inspired by this piece, Marc Roberts, perhaps the world's best — and only — climate cartoonist, reposted a hilarious take on the bathbub effect.]

In a tub, this is a recipe for a flood. In the climate system, Dr. Sterman says — echoing many climate scientists — it is a loud message that a prompt start is needed in curbing and then cutting emissions if you want to cut the chances of passing dangerous thresholds. He recently wrote a Policy Forum paper in Science reviewing his and other research on widespread misunderstanding of this kind of risk, including a 2007 study he was a co-author of in which 84 percent of 212 M.I.T. participating grad students drew curves for proposed emission trends that would result in concentrations continuing to climb.

"The erroneous belief that stabilizing emissions would quickly stabilize the climate supports wait-and-see policies but violates basic laws of physics," Dr. Sterman concluded.

I sent him the study from the Proceedings, which was led by Susan Solomon, who also led a five-year review of science that culminated in the main report in 2007 by the Intergovernmental Panel on Climate Change. His response is worth reading, and is included in toto below.

Dr. Sterman and other social scientists assessing climate science and climate policy say that a vital task for President Obama and his climate-energy team (and for scientists and the media), even as they weigh legislation and a treaty and technology, is to educate the public on the bathtub effect.

Without greater understanding of the nature of the problem, he says, it will be hard to convince the public of the need for big, prompt, costly changes to the energy system, even when the worst impacts are projected to come later in the century.

The long lifetime of carbon dioxide in the atmosphere, and the long lifetime of sources like coal-burning power plants once built, mean that the "faucet" for CO_2 is getting cranked open just when it should be going in the opposite direction. Across Cambridge at Harvard, Kimberly Thompson holds the same view.

In a recent email, she said anyone thinking effective policy can be crafted only by society's elite is engaged in wishful thinking.

> I don't believe that experts alone can solve the climate change issue," she said in an email. "I'm with Thomas Jefferson, who said: "I know no safe depository of the ultimate powers of the society but the people themselves; and if we think them not enlightened enough to exercise

> their control with a wholesome discretion, the remedy is not to take it from them, but to inform their discretion by education. . . .” Bottom line from my perspective — we need education that helps correct people’s mental models. . . .

You can try an exercise Dr. Sterman created on the greenhouse bathtub problem online. He wrote a fascinating piece for the journal Science on the results of a study testing hundreds of very smart M.I.T. students to see if they could draw an emissions curve that would stop the level of carbon dioxide in the atmosphere from rising.

To those eager for more, here’s Dr. Sterman’s reaction to the Solomon et al paper:

I have read the Solomon paper.

It’s an excellent demonstration of the bathtub principle — the concept of stocks and flows, which prior research shows many people, even many highly educated people, don’t understand. Our mental models suggest that if we stop the growth of emissions, we will stop global warming, and if we cut emissions, we’ll quickly return to a cooler climate. We tend to think that the output of a process should be correlated with — look like — its input. If greenhouse gas emissions are growing, we think, the climate will warm, and if we cut emissions, we imagine that the climate will cool. In systems with significant accumulations, however, such correlational reasoning does not hold. Rather, it’s more like filling a bathtub. The amount of carbon dioxide in the atmosphere is like the level of water in a bathtub. The level grows as long as you pour more water in through the faucet than drains out. Right now, we pour about twice as much CO2 into the atmospheric tub than is removed on net by natural processes.

Stabilizing atmospheric concentrations requires emissions to fall to the net removal rate. Further, because of the processes highlighted in the Solomon paper and other analyses, including the IPCC AR4, the net removal of CO2 from the atmosphere is likely to fall as the stocks that absorb all that carbon, particularly the oceans, fill up. There are other key “bathtubs” — accumulations — that contribute to the irreversibility of climate change Solomon highlights. First, global mean surface temperature depends on the quantity of heat stored at the surface of the earth (earth, lower atmosphere, and the mixed layer of the oceans). That stock of heat is increased by net radiative forcing, the difference between the flow of energy coming in (primarily from the sun) less the flow of energy radiated back to space and the flow of heat transfered to the deep ocean. Today that inflow exceeds the outflow, so the average temperature is rising. Stabilizing the concentration of greenhouse gases in the atmosphere may stop the growth in net radiative forcing, but will not reduce the net inflow of energy (net radiative forcing) to zero. So temperatures will continue to rise until the planet warms enough to restore radiative balance. Solomon’s paper points out that the heat currently absorbed by the oceans does not disappear, but eventually returns to warm the surface. Thus temperatures won’t fall quickly even if atmospheric GHGs peak and eventually drop. And so on. Land-based ice in glaciers and ice-sheets will keep contributing to sea level rise as long as melting exceeds snowfall accumulation; stopping the growth of temperature would not stop the net melting.

What all this means is that the rate at which the climate returns to “normal” — say, early 20th century conditions — is so slow that, for key factors like sea level, precipitation patterns, ice sheets, and so on, the flow out of the bathtub is very very slow. So climate is a bit like the national debt. The US federal deficit has exploded in recent years, and the national debt has exploded as well. But suppose we could instantly cut the deficit to zero — drop it from about a trillion dollars per year to zero. What would happen to the debt? Of course it would not fall, but would instead stop growing at its all time peak value. Because the drains out of the various bathtubs involved in the climate — atmospheric concentrations, the heat balance of the surface and oceans, ice sheet accumulations, and thermal expansion of the oceans — are small and slow, the emissions we generate in the next few decades will lead to changes that, on any time scale we can contemplate, are irreversible.

One more critical point: it’s important that people not react to Solomon’s work with despair. Yes, a

certain amount of climate change, due to past emissions, is inevitable, and will not be reversible. But it would be tragic if people concluded that therefore there is nothing we can do, that it is futile to reduce emissions, and that therefore all efforts should shift to adaptation. To the contrary: if nothing is done to cut emissions, and soon, the climate our children and grandchildren will face will almost certainly be far less hospitable, and there will be no turning back. By the time we know for certain how bad it will be it will be too late to take any corrective action. The Solomon paper should finally bury the idea that we can wait and see. It further strengthens the case for immediate, strong mitigation. The good news is that it's getting cheaper every day to cut carbon emissions. Through learning, scale economies, R&D, and other forms of innovation, new technologies for carbon-neutral renewable energy are becoming more available and less expensive. Each megawatt of solar or wind capacity we build lowers the cost of the next and the next — a positive feedback we need to strengthen if we are to avoid irreversible harm to the ability of the planet to sustain us.
Best

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Notes

[1] http://dotearth.blogs.nytimes.com/2009/01/28/the-greenhouse-effect-and-the-bathtub-effect/