Science Fact

Veiling the Earth

Gregory Benford

This article is a companion to "Cooling Chaos" on page 120 and may contain spoilers.

We are losing the war on carbon dioxide, so politicians are now playing the posture game. Companies are the enemy, because . . . well, they give us what we want: more. Big Oil doesn't burn their product; we do. So businesses polish their images, tipping the hat toward minor adjustments. Herd behavior.

No economist I know thinks we can replace even our current energy sources with renewables in less than half a century. Some estimates say we'll have to cut CO_2 emissions in half within 12 years to avert major warming. Of the 195 signers of the 2016 Paris Agreement, a mere 17 have met their self-assigned targets.

Why? Shutting down and replacing the second largest global industry (after farming) is hugely expensive. The Green New Deal batted about now would cost $6,400 per American per year. Future expected energy use looms large. Stanford's Ken Caldeira and a gang of us in 2003 calculated that future carbon-free energy will mean the equivalent of a nuclear reactor every day from 2003 to 2050.

Not gonna happen, no.

Energy and tech innovations, not hysteria, will work better.

There are at least two (barely examined) ways to stop the greenhouse impacts to come: draw CO_2 from the air or reflect sunlight. Neither has any traction so far. Governments have devoted only tiny sums to their study.

But capturing carbon from the air and storing it is vastly expensive—about 40% of the world's productivity. Plus, our fossil fuel burning is accelerating, not declining.

So we should also consider relatively low-tech, low-expense experiments, to do two things:

- accelerate our understanding of climate science, by perturbing the system and seeing how it responds—a standard experimental technique, and
- cool regions of the world, working toward restoring the climate we prefer. Change the climate on purpose instead of heating it by mistake, as we are doing now.

My story in this issue reflects a lurching, alarmed way this might happen—by expanding earlier ways to screen smaller fires and heat waves. Here I show systematic paths we can follow. In doing so, we become stewards of the Earth.

What could be more intuitively appealing than simply reflecting more sunlight back into space, before it can strike the surface, be emitted in heat radiation, and then absorbed by CO_2?

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Albedo Chic

The National Academy 1992 panel found that ". . . one of the surprises of this analysis is the relatively low cost" of implementing some significant measures. Even if their rough estimates are wrong by a factor of ten, they are striking. It might take only a few billion dollars to mitigate the U.S. emission of CO_2. Compared with stopping people in China from burning coal, even hundreds of billions are nothing.

Perhaps the greatest unknown is social: how will the politically aware public (those who vote, anyway) react?

If they are painted early and often as Doctor Strangeloves of the air, the stewards will fail. In Fall 2006, *Rolling Stone* titled its story on this idea, and particularly on my collaborator, Lowell Wood, as "Dr. Evil Saves the World," but the piece was actually pretty even-handed. On the other hand, properly portrayed as allies of science, the small band working on these ideas could become heroes.

A crucial factor here is whether the agenda looks like another top-down contrivance, orders from the elite. A Draconian policing of illegal fuel-burning will indeed look this way, but mitigation doesn't have to. It will play out far from people's lives, out at sea or high in the air.

Better, perhaps widespread acceptance of mitigation strategies could lead to an "albedo chic"—using the physics word for reflectivity—with ostentatious flaunting of white roofs, cars, the return of the ice-cream suit in fashion circles. White could be appropriate after Labor Day again.

More seriously, simply adding sand or glass to ordinary asphalt ("glassphalt") doubles its albedo. This is one mitigation measure everyone could see—a clean, passive way to Do Something. Cooler roads lessen tire erosion, too.

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Active Measures

We must begin thinking beyond studies and reports to controlled experiments. Climate scientists have so far studied passively, much like astronomers. They have a bias toward this mode, especially since the discernible changes we have made in our climate have been generally pernicious. Such mental sets ebb slowly. The reek of hubris also restrains many.

Careful climate modeling must closely parallel every experiment. Few doubt that our climate stands in a class by itself in terms of complexity. Though much is made of how wondrous our minds are, the biosphere is perhaps the most complex entity known—and we take it for granted. Absent a remotely useful theory of complexity in systems, we must proceed cautiously.

Having sinned against Mother Nature inadvertently, many are keenly reluctant to intervene knowingly. Nobel laureates have generally sided with the Puritan position, adding considerable weight to the cause of abstention—which we now see failing.

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Veiling the Arctic

One proposal Lowell Wood, Ken Caldeira, me, and others have worked on is keeping the polar bears from going extinct. This would entail stopping the tundra thaw, which releases much methane and CO_2.

Sunlight falls most weakly in the Arctic and Antarctic, yet these areas show the greatest rate of change due to air and ocean warming. In the Arctic, particularly, the warmer ocean melts ice, exposing more ocean, which is darker than ice. So the ocean absorbs more sunlight than before. Very simply, this and other effects are warming the Arctic more than other regions—about 5 degrees Centigrade in the last 30 years, with rates accelerating.

The Antarctic is thick ice mostly on land, so melting doesn't expose as much of the darker ocean as in the Arctic. The whole subject is complicated, but the conclusion is not: the Arctic seems the best place to use advanced methods of restoring the climate. Climate models show that cooling the Antarctic as well as the Arctic disturbs the rest of the planet less, by keeping the climate global symmetry. Both would cool their hemispheres' temperate zones in their summer, at a cost of less than ten billion dollars.

If we understand climate well enough to predict that global warming is a problem, then plausibly we also understand it well enough to address the problem by direct means. But the central issue is that we do not have time to waste.

Many predict that we will see more severe warming effects, in the Arctic and globally, within a few decades. Ocean acidification takes longer, suggesting a simple priority:

- begin with regional, reversible experiments to define the science
- learn from these how well we understand our climate
- look for cooling effects
- stop the warming to buy time
- deal with ocean acidification separately
- focus on what we can do now, not what we can do eventually.

We do not have "eventually"—nature works at its own pace.

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A Particulate Shield Experiment

Perhaps the simplest idea uses the suspension of tiny (less than one micron), harmless particles at such altitudes that they will rain out within, say, six months. These will reflect mostly ultraviolet, which has a lesser role in plant growth than the lower frequencies, yet carry more energy, which heats when absorbed.

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This describes a scientific experiment, designed to understand the complex climate system, not the beginning of an engineering project. If the experiments work, we can define what engineering to do.

A first test could be over the Arctic, since the warming there is considerable. There the atmospheric circulation patterns tend to confine the deployed particles, sweeping them around the pole but not far southward. The general method seems clear:

- Deploy the particles by airplane in the spring.
- Measure the cooling below, using local sensors and space monitoring of the sea ice.
- Detect if the present retreat of sea ice toward the north pole slows or even reverses. This will be a clear, visual signature that the region is cooling. Polar orbiting satellites can refine the analysis.

Ground measurements will give more refined understanding. The particles can rain or snow out in fall, ending the experiment in predictable fashion.

One could use just enough of the tiny particles to create a readily measurable shielding effect—a *veil,* to use the term of Oliver Morton in his useful book, *The Planet Remade*. An initial experiment could occur north of 70 degrees latitude, over the Arctic Sea and outside national boundaries. The particles would reflect mostly UV rays back into space. They would reduce warming, and stop the harm of UV rays to plants and animals as a side effect. Robust photosynthesis would still occur in the tundra, fueled by the visible spectrum.

This idea exploits our expanding understanding of the climate system. It also uses our historical knowledge of the marked cooling driven by volcanoes in the last several centuries, from sulfate aerosols at high altitude. But sulfates interact chemically with the high altitude air. We can avoid that by using less chemically reactive particles, such as diatomaceous earth—the fine-grained particle used in pool filters. Our aim should be to edit the incoming sunlight, not to interfere with our atmosphere's chemistry.

Ken Caldeira, who holds a chair at the Carnegie Institute at Stanford University, has modeled the idea of Arctic cooling. The figures here present his preliminary findings, which show that a full-scale program of adding aerosols at stratospheric levels could restore the Arctic within a few years.

A few years ago, Caldeira set out to disprove an idea put forward by Livermore physicists Lowell Wood and Edward Teller to cool the Earth with a sheet of superfine reflective mesh—similar in concept to orbiting mirrors.

In a computer model, Caldeira and colleague Bala Govindasamy simulated the effects of diminished solar radiation. “We were originally trying to show that this is a bad idea, that there would be residual regional and global climate effects,” explains Dr. Caldeira. “Much to our chagrin, it worked really well.”

When I suggested the Arctic strategy, he tried a similar simulation with Wood. It worked, too.

Scientists routinely use computer models to simulate climate-related scenarios, from rising CO_2 levels to the impact of deforestation on global warming. After several weeks of running a climate simulation on Stanford’s superfast computer network, Caldeira concluded that shading the sunlight directly over the polar ice cap by less than 25% would maintain the “natural” level of ice in the Arctic, even with a doubling of atmospheric CO_2 levels. Push the shading up to 50%, and the ice grows. We could have a new ice age if we wanted it! Even better, the restoration happens fast: Within five years, temperatures would drop by almost two degrees.

Another friend, Lowell Wood, calculated that roughly 300,000 metric tons of particles each year—a tiny amount, on a planetary scale—could shade the sunlight in the Arctic by 25%.

How to get those particles up there? A half-dozen K-10 Extenders could do the job in a summer. The McDonnell Douglas KC-10 Extender is an aerial refueling tanker aircraft, essentially a sausage with internal links that can be adapted to spray liquid water with particulates. In the plume can be sulfur dioxide—the reflector that cools our planet when big volcanoes like the 1992 Pinatubo eruption occurred—or something alkaline, like calcium carbonate. In the fall, the particles of chemically inert, sub-micron size fall to the lower atmosphere and fall out in rain or snow. The K-10 Extenders are in ample supply because they are slated to be upgraded. Their ceiling is 42,000 ft (12,800 m), so can reach the stratosphere over most of the globe.

We could stabilize the ice, save the polar bears, and demonstrate the virtues of planetary engineering for less money than it took to run the Iraq war for a month. Because the Arctic winds swirl around the pole, and there are few people above 70 degrees latitude, there seems little effect on society, even if something goes wrong. And if it does, we can turn off the seeding in an hour, letting the particles come down in months.

But getting the science right may be the least of it. All the real complexity is in the politics.

For whose hand will be on the global thermostat? The Inuits won’t like the idea of a warming Arctic, but the Russians will. It is opening shipping lanes already, making oil and gas exploration easier. The Russians have already laid claim to these resources, and a half dozen other nations have disagreed.

This worries many. “Will we have Greenland and Bangladesh arguing over the ‘right’ temperature?” says Richard Alley, a Penn State paleoclimatologist. “Will your neighbor try to sue somebody if the tomatoes freeze?” This can be avoided by directly setting aside such lawsuits, actions through legislatures themselves—and perhaps, in the USA, aided by executive orders.

Once you commit to countering the rise of CO_2 emissions with a veiling scheme, Alley adds, you’re hooked. “This is not something you can do for twenty or thirty years, then quit.”

Even Ken Caldeira views veiling as, at best, a way to buy time to develop clean energy technologies. “As a long-term strategy,” Caldeira says, “it’s nuts.”

But not trying it seems nuts, too. The polar bears don’t vote, but I bet I know how they would do so.

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The Long View

We can regard these ideas, and the scientific knowledge we gain from such experiments, as tools in a possible future technology. There could be many useful variables in such a climate technology, including particle size and nature, altitude deployed (and therefore duration in the atmosphere), and much else. We very probably do not even know all the major influences we will find.

If such an Arctic experiment works, it could tell us much about how to possibly arrest Arctic warming and reverse the loss of sea ice. Since few live there, any side effects could be minimal. By placing the particles at a high altitude, we can arrange for the first experiments to end when they rain out into the sea, after the main heating during Arctic summer has passed.

Repeating this over several years, to advance our understanding of how our vastly complex climate works, would advance the science. Public discussion could run in parallel, giving the sense that this momentous issue is being freely aired.

This idea is only the first step in moving climate science from passive observations to an active science, just as the space program allowed astronomy to give us the power to explore the planets a half century ago. We now do experiments on the soil of Mars and the atmosphere of Jupiter and Venus. With direct measurement comes a new era in any science. All of particle physics has a similar history.

So this is not a new transition in science, but it is unique: we live inside the experiment. We have far more at stake. And we must be quick.

Diagnosing global climate change is only the beginning. Restoring the stable climate we are now losing is the true, long-range goal. But the science comes first.

Saving the Arctic can be the first, trial step. If we find that the pace of forced global climate change is unacceptably high, we could then put this idea to work globally, with all deliberate speed. There could be other side effects on the vastly larger global scale, and we would have to monitor the entire process very carefully. Some effects could be positive. Lessening UV would lower the human death rate from skin cancer, now about a million per year. Crops under less UV grow better, yielding more food, especially in the tropics.

The main thrust of all this is to carefully use our ability to attack warming at its roots—incoming sunlight now, carbon dioxide later. First things first.

The climate system has great inertia and stirs slowly, but once altered, has a momentum of its own. It will be a good idea to have methods like these on the shelf, to deploy quickly. Methods studied this way would be ready for use if the global environment worsens. Given signals that the scarier scenarios of a warming climate might be soon upon us, we could act soon.

Such preparations can also establish the political ground for widespread action. Humanity needs to get used to the idea of acting in this wholly new fashion, assuming our role as true stewards of the Earth. Given the magnitude of the possible threat to all societies, such preparations are merely prudent, not radical.

Costs seem readily attainable—a few hundreds of millions of dollars for an Arctic experiment. High altitude trials over the open ocean are little constrained by law or treaty, so showstopper politics may be avoided. The first stages will be scientific experiments, not vast engineering projects.

Many have done computer simulations of veiling the globe. That's hard because our stratosphere is hard to reach—above which veiling particles can survive for months or even years. Near the equator, the stratosphere starts at as high as 20 km (66,000 ft; 12 mi), around 10 km (33,000 ft; 6.2 mi) at middle latitudes, and at about 7 km (23,000 ft; 4.3 mi) at the poles. KC-10s can operate above the stratosphere until within about 20 degrees of the equator. Alas, equatorial areas are most vulnerable to warming. Cooling the whole rest of the planet would reduce tropical temperatures substantially. Or the next generation beyond the KC-10s could perhaps reach even above the tropical stratosphere.

Whatever experiments we try, the point is to get started. A favorable experiment could change the terms of the global warming debate for the better. As economist Robert Samuelson recently said, "The trouble with the global warming debate is that it has become a moral crusade when it's really an engineering problem. The inconvenient truth is that if we don't solve the engineering problem, we're helpless."

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Taking Over, Forever?

A decision to face our role as stewards, and intervene knowingly, globally, would be a watershed in human history.

Managing the entire planet, and so ensuring an enduring legacy, is surely a more striking prospect than the makers of any deep time message have ever contemplated. Yet doing so will make an explicit connection with distant eras, which unknowingly bequeathed us an altered landscape. Such links are made concrete in the transformed world we now inhabit, a "natural" environment far removed from that of our Pleistocene ancestors.

Once taken up, such a monumental task cannot be put down. As long as we exert so powerful a presence, we shall have to be mindful of it. Perhaps the worldview needed can emerge from such philosophers as Martin Heidegger. In his perspective, technology "enframes" us, leading humanity to more and more see the world as a *bestanden,* a "standing reserve." In turn, we regard other humans as resources, reducing our unconscious respect for both them and their environment. Heidegger is abstruse but influential and may point the way toward a philosophical shift necessary for true stewardship.

It is small consolation to estimate that we may well consume nearly all fossil fuel reserves within five hundred years—mostly coal and oil shales—and certainly will within a millennium. This assumes we will use them as our principal energy store. Of course, other sources might turn up. Within a century or so our descendants may view with horror the burning of the long hydrocarbon chains bequeathed by geology. They may feel oil should properly be employed as lubricants and manufacturing fluids, rather than plundered for simple energy content.

Once we become caretakers, we cannot stop. The large tasks confronting humanity, especially the uplifting of the majority to some semblance of prosperity, must be carried forward in the shadow of our stewardship.

Should world civilization fall, our hand would slip from the helm, and the planet could fare badly. Unless we've reduced the greenhouse gases in our air, we'll experience a sudden shock of new warming, since we'll have lost our reflecting screen.

So if we elect to guide the planet so that it may support so many of us in high technological civilizations, we will have to exert wisdom and cleverness throughout centuries-long agendas. Nature in her largeness and largess responds with ponderous grace on the scale of centuries or more. Our frenetic energies expend themselves within a decade or two, the typical scale for even the most far-reaching customary projects.

This mismatch in time scales implies that we must cultivate a farsighted judgment rare in our societies, ancient or modern. Becoming aware of how we leave our mark on the world will demand a cultural evolution profound and, to many, puzzling.

And there are always tradeoffs. We now know that the aerosols we've put into our air, starting with extensive coal burning two centuries ago, reflect sunlight, and so cool the world. But such pollutants give us higher rates of lung cancer and emphysema. If we clean our air, we live longer on average—but we get more warming. So: do our reflecting in the stratosphere. Nobody likes these benefit antagonisms, but they inevitably come with the task of managing natural systems.

To close, a few numbers. I calculated that the thermal expansion of our oceans can be stopped by blocking a mere 2 Watts/square meter around the globe. A Stanford climate simulation backed this up in detail. That's a tiny fraction of the 1360 Watts/square meter we get on average at the top of the atmosphere. But veiling the world doesn't have to be uniform. Covering a fraction of the planet, we could stop the rising seas and save both Arctic and Antarctic during their summers, from the poles down to thirty degrees lower—that is, to 60 degrees latitude in each hemisphere. In those regions few people live, especially in the Great Southern Ocean. The cost?—a few billion dollars a year. At that, we need only reflect back about 31 Watts/square meter, easily done by increasing the aerosol density.

Solving the heating problem and the oceans' expansion is a beginning. When it works, people will become more welcoming of further steps. The harder issue is our oceans' increasing acidity, from absorbed carbon dioxide. That we can fix by putting large masses of alkaline soil in the oceans. This will take huge masses–tens of billions of tons of, say, chalk, per year. Brute force, but an emergency solution.

Many think climate change is a moral problem. But it's really an engineering problem, properly seen. Many shall object, of course, to seeing it so.

Still . . . what other choices have we?

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Further Reading:

"Advanced Technology Paths to Global Climate," *Science,* Vol 298, Issue 5595, 2002

The Planet Remade: How Geoengineering Could Change the World, Oliver Morton (Princeton: Princeton University Press, 2015), 440 pp., $29.95

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