Broecker Brief #9

Let's Take Geoengineering out of the Closet

Introduction

After 60 years of grappling with various aspects of the outgoing buildup of CO_2 in the atmosphere, I have come to the conclusion that it is time to think seriously about cooling the planet by putting SO_2 into the stratosphere. I say this because were we to do this, we could ease several of the threats we face:

1) the northward shift of rain belts,
2) the melting of ice and the rise of sea level,
3) the back and forth migration of wildlife,
4) the intensification of storms,
5) the bleaching of coral.

Until the election of Donald Trump I viewed geoengineering as something we would do only if a worst case scenario became a reality. But my thinking has been shifting. As outlined below, I view the trade-off between problems created by albedo modification to be far smaller than those we are creating by the continuing buildup of CO_2 in the atmosphere.

In writing this I am fully aware that almost everyone thinks that geoengineering should remain in the closet. The most often heard argument against it is that, were we to go this route, the incentive to transition to alternate energy sources would be greatly weakened. The next most common argument is that, as the integrated impacts on individual countries would certainly vary, SO_2 cooling could well lead to international conflict. Yet another is that, if for some reason we were to stop putting SO_2 into the stratosphere, a disruptive warming would occur. Although I sympathize with each of these arguments, one has to weigh them against the problems reflective cooling might ameliorate.

Stemming the Northward Shift of the Planet's Rain Belts

The Earth's northern cap is currently warming much faster than its southern cap (see Figure 1). Based on records for the last 50 thousand years kept in geologic archives (i.e., stalagmites, polar ice, ocean sediments, lake shorelines…), a strong case can be made that the Earth's rain belts are tied to the latitude of its thermal equator. The reason for the asymmetry in global warming is that the ratio of land area to ocean area is much larger in the northern than in the southern hemisphere. As land has little heat capacity, it warms rapidly. By contrast, as the ocean has an enormous heat capacity, it warms slowly.

The western U.S.A. bears witness to the importance of such shifts in the thermal equator. Prior to 14.6 thousand years ago, the closed basin lakes in Nevada covered about ten times more area than today's. The reason is that the northern Atlantic was covered with winter sea ice pushing the thermal equator to the south. This shifted the boundary between wet Washington - Oregon and dry California - Nevada to the south. Then, 14.6 thousand years ago, ocean circulation reorganized eliminating the sea ice. This allowed the thermal equator to move back to the north. Lakes in the Great Basin dried up.

A reasonable case can be made that California is currently responding to the preferential heating of the northern hemisphere. Its climate is becoming more like that of the Mojave Desert and less like that of coastal Oregon.

We know that the northward shift of the thermal equator which occurred 14.6 thousand years ago had widespread impacts. For example, the drying of the western U.S.A. was matched by a strengthening of the Asian monsoon.

Were we to cool the planet by increasing its reflectivity, the northern hemisphere would, for the same reasons, cool faster than the southern hemisphere. This would likely ease the drought in the western U.S.A.

Melting Glaciers and Rising Sea Level

Those who study glaciers, make a strong case that the dominant driver of change is summer temperature. Further, it is well documented that almost all the world's mountain glaciers are currently retreating. Greenland's ice cap is also responding. Its outlet glaciers are retreating and summer melt is occurring at ever higher elevations.

In addition to marring the Earth's beauty, ice melt threatens to raise sea level. Over the past 5 years, two disquieting observations have been made. First, the dating of raised coral reefs on the Seychelles Islands confirms that during the last interglacial period sea level stood 5 to 9 meters higher than now. Second, the documentation that cosmic ray-produced radioisotopes ^{10}Be ($t_{½} = 1.4 \times 10^6$ yrs), ^{26}Al ($t_{½} = 0.7 \times 10^6$ yrs) and ^{36}Cl ($t_{½} = 0.35 \times 10^6$ yrs) are present in the granite beneath the ice in central Greenland can only be explained if this ice cap was absent one or more times during the last 400 thousand years. As none of the four interglaciations during this time interval were more than a degree or two warmer than the present one, taken together these two findings are a cause for concern. Were we to leave the CO_2 we have and will produce by burning fossil fuels in the atmosphere, we risk a major rise in sea level over the next few hundred years. Further, it will not be reversible. Clearly cooling the Earth's summers would lessen this threat.

The Shift in Wildlife Habitat

Taken together, the warming of the planet and the northward shift of its rain belts will disrupt the Earth's ecosystems. Opportunistic life forms will respond to these changes by migrating. So will human beings. If we allow a major warming to occur and then at a later time alleviate it by capturing and burying CO_2, we will cause a second such disruption. Clearly by adjusting the reflectivity of the planet, we could decrease the magnitude of this ecologic 'hump'.

Intensification of Natural Disasters

The frequency of forest fires and the intensity of hurricanes has increased. Many experts implicate global warming. If this assessment is correct, then cooling the planet should alleviate these impacts.

Coral Bleaching

Coral reefs are subject to many environmental insults. Although overfishing and algal blooms are partly to blame, bleaching during particularly warm summers is thought to be the most damaging. If so, cooling the planet's summers would reduce the toll. But environmentalists would counter "doesn't ocean acidification play a role?" Yes, but in my view only a minor one.

As the tropical ocean is highly supersaturated with respect to aragonite, there is no danger that it will become undersaturated. Experiments show that the ongoing decrease in carbonate ion will slow coral calcification a bit but won't pose a threat in any way comparable to bleaching.

Carbon Capture and Storage

At this point one might ask "instead of geoengineering why not capture carbon and store it?" Of course, at some point this will have to be done. But even if we had done our homework and it was now shelf ready, it would be far too slow. To understand this one has to be aware of the immensity of the task. Were it done by air capture, using modules which capture one ton of CO_2 per day, one hundred million such units would be required just to match today's CO_2 generation. To bring CO_2 down by 2 μatm/yr would require an additional one hundred million units. To bring it down by 20 ppm per year would require a billion such units. As each unit would cost about 25,000 dollars, a billion such units would cost about 25 trillion dollars. To operate them and store the captured CO_2 would cost perhaps another 10 or so trillion dollars a year. Clearly, this is not something the world will take on during the next several decades. By contrast, cooling with SO_2 would be on the order of two orders of magnitude cheaper. Plus it would be fast acting.

How Might We Proceed?

As is the situation for CO_2 capture and storage, a long lead time would be required before it could be implemented on a large scale. As the same is the case for SO_2 cooling, the world would be better served if the required research were carried out quietly before implementation became a political issue.

Were we to move toward SO_2 cooling, we would have to find a way to transport millions of tons of SO_2 to the stratosphere in such a way that would spread it uniformly across the planet. Large balloons would be the likely carriers. Atmospheric models would provide a first order strategy for locating the launch sites and heights in the stratosphere at which the SO_2 would be injected. Tracer experiments could be used to test these models. Further, its downsides (ozone depletion, sky bleaching, acid rain, non-uniform cooling, cooling transients) would have to be explored.

Opponents will quickly point out that rather than thinking in terms of geoengineering, we should put all our effort into transforming our energy supply to solar, wind and nuclear. Of course, this must be our goal. My fear is, however, that this transition will take many decades and during this time our planet will be subject to a host of insults which could be avoided were interim SO_2 cooling be put in place. The fact is that over the last 50 years the ratio of energy from fossil fuels (85%) to that from other sources (15%) has not changed. Several billion people still live in poverty. Any proposal for a tax on fossil fuels designed to pay for the capture and storage of CO_2 is political death. Those who own fossil fuel reserves will do everything possible to make sure they are burned. I wish that I could be my usual optimistic self and believe those who say we are on the brink of an energy revolution. But I can't.

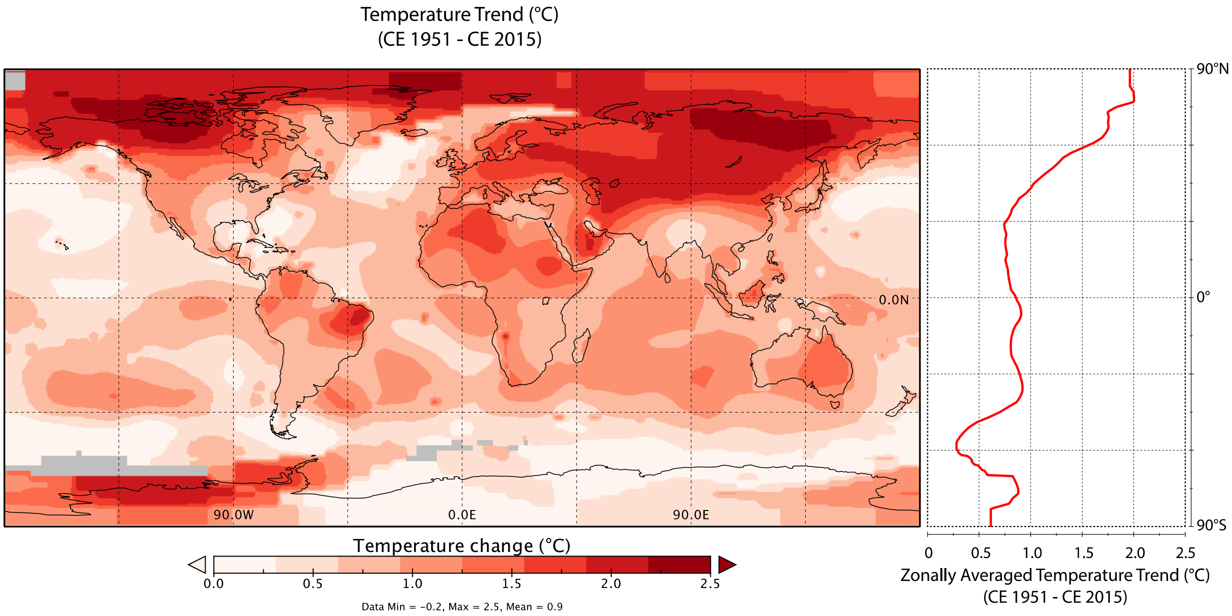

Figure 1. Globally distributed temperature trends between CE 1951 to CE 2015. Left: Global map of temperature trends calculated for the period CE 1951-2015. Right: Zonally averaged temperature trends. The northern middle and high latitudes have warmed roughly twice as much as corresponding southern latitudes over the past half-century or so. Plots based on GISTEMP (Goddard Institute for Space Studies Surface Temperature Analysis) Reanalysis data set (96, 97).

References

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