ENVIRONMENTALLY SPEAKING

Peter Schwartzman

Greenhouse gases: so sparse, yet so powerful

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With all the talk about the prospects of climate change, including international debates focused on the viability of reduced gaseous emissions, one centrally-important consideration often gets ignored. It turns out that the greenhouse gases that contribute to warming the earth constitute only about 1 percent of all gaseous atmospheric material. And if one considers only the subset of these gaseous molecules whose concentrations are thought to be altered by human activities, their atmospheric contribution drops to well below 1 percent. In the past 50 years we have begun to realize that these additions to our atmosphere, which come primarily from fossil fuel burning, will likely have significant impacts on human and ecosystem health and welfare.

Simply put, these "new" gases, despite their low relative concentrations, have and will continue to demand our attention from political and economic points-of-view. Remarkably, albeit so small in percentage terms, greenhouse gases are critical to our maintenance of a planetary atmosphere conducive for life. Recognizing how such a minute portion of our atmosphere affects humans so significantly is a first step towards understanding why seemingly small quantities matter and likely a requisite step for living in a sustainable way. (Quantities are small in relative percentage terms, but in net emission terms, the U.S., alone, emitted a staggering 89 billion pound of CO_2-equivalent greenhouse gas in 1998!)

Probably the resource most taken for granted in this world is the air, particularly the oxygen that we breathe. Most of us could last several weeks without food and a few days without water, but very few of us can survive for more than minute or so without air. Both humans and animals need a constant supply of oxygen or our bodies shut down. Thankfully, the atmosphere is plentiful with this resource. Currently, the oxygen (chemically, O_2) that we require takes up nearly 21 percent (by volume) of the air that we breathe; most of what we breathe in is nitrogen (N_2, dominant to the tune of 78 percent) which, strangely enough, has little known purpose ingested into the body in gaseous form. Now while this vital resource is found in relative abundance, other essential gaseous resources are much less common.

Specifically, the greenhouse gases which enable the earth to be 59°F (or 33°C) warmer, and therefore habitable for most modern life forms, are much more scant than oxygen. In 1884, Samuel Langley, a physicist studying the sun's heat as measured at the Earth's surface, determined that the atmosphere's ability to selectively absorb radiant energy (i.e., light) enables the Earth to be much, much warmer. (Christianson, 1999). Now, while Langley greatly overestimated the atmosphere's temperature enhancing effects, he was very much on track in that the atmosphere provides a tremendous utility in controlling our climates. So what is it about the atmosphere that gives it this ability?

Most gases in the atmosphere do little to enhance global surface temperatures, in fact, the two most abundant gases, namely nitrogen and oxygen, contribute little or nothing to increased temperatures at the surface. However, some gases, known as greenhouse gases, have a very special property that enables them to warm the Earth's near surface environments substantially. Specifically, these gases, which include (in order of decreasing abundance) water vapor (H_2O), carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), ozone (O_3), and a variety of chlorofluorocarbons, have the property that they are nearly transparent to visible (i.e., Sun) light but absorb great quantities of earth light. Earth light, a.k.a. infrared light, is emitted by the earth and can only be observed by humans with the use of special optical devices, appropriately named "infrared" binoculars. It is through the absorption of this light and the subsequent reemission of much of it back towards the Earth's surface that enables the atmosphere to serve as a blanket — a process often referred to as the "greenhouse effect."

Of all the many greenhouse gases, carbon dioxide certainly gets the most attention. While much of this attention is well-deserved because of CO_2's likely impact on "global warming," too often a focus on CO_2 alone obscures the larger problem. Since the mid-1800s, many greenhouse gases have been rising steadily in concentration through emissions from various human activities. CO_2, the most important of these due to its much larger abundance, has been exponentially increasing in concentration through the enhanced emissions from fossil fuel burning associated with the onset and continued industrialization of the world's economy. (Water vapor is much more important than CO_2 in terms of greenhouse impact, but it gets very little discussion in the "global warming" debates because scientists generally don't think that its atmospheric concentrations have or will change appreciably in the future.) An analysis of air bubbles trapped in polar ice tells us that background (pre-industrial) levels of CO_2 concentrations were about 280 parts-per-million (ppm) while current levels have been found to be roughly 370 ppm, an increase of 32 percent.

Yet, CO_2 isn't the only gas that is undergoing greater levels of emissions due to expanding industrial processes. For instance, CFCs, which constitute a group of many larger molecules containing carbon, chlorine and fluorine, didn't exist on Earth until the late 1930s when they were created and mass-produced as an inert, miracle gas for refrigeration and air conditioning devices. Thus, concentrations of CFCs in 1930 were 0 ppm while concentrations in 2000 average about 700 ppt (parts-per-trillion), clearly a substantial growth pattern over a small period of time. Unfortunately, it took more than 50 years of the use of CFCs before scientists determined how detrimental this innocuous gas was to our livelihood. Ozone (O_3), another greenhouse gas, is formed in the troposphere (i.e., lower atmosphere) as a byproduct of solar light stimulating reactions among tailpipe emissions, and ranges in concentration

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from ~60 ppb (parts-per-billion) in the troposphere and ~1000 ppb in the upper atmosphere (where is created by alternative means). Ozone has one of the most complex and confusing atmospheric distributions and impacts on incoming and outgoing radiation — both of which have substantial importance on biological health. Nitrous oxide (N_2O), a.k.a. laughing gas, is a greenhouse gas produced in the production of pantyhose, among other nylon products, and has an average atmospheric concentration of 0.3 ppm.

The existence of the above greenhouse gases is known to keep the planet much warmer and without them the earth would be virtually uninhabitable for most current life. And, does a 32 percent increase in CO_2 concentrations over 150-250 years seem like a lot or does the fact that even today only 4 out of every 10,000 gaseous molecules are CO_2 (the same as 370 per 1,000,000) appear significant? Not obviously, no.

So why then is there so much fuss about them? Well this seemingly simple question can be answered succinctly by considering five important scientific findings that have been obtained since the middle of the 20th century.

First, all of these gases have and will continue to increase in concentrations at an exponential rate well into this century given a business-as-usual scenario. Currently, levels of most of them are well-above background concentrations observed over the past 160,000 years of earth's history. Humbling as well is the recognition that despite these expected increases in gaseous concentrations, greenhouse gas concentrations will still remain well below 1 percent into the forseeable future.

Second, higher levels of greenhouse gases correlate very highly with higher global temperatures. In fact, complex climate models predict that global average temperatures are likely to rise between 2.7-6.3°F (or, equivalently, 1.5-3.5°C) by 2100. These predicted temperature changes are significant because they suggest that the earth may become as warm or warmer in this century (21st) than it has been in nearly 200 millennia. Third, these temperature changes are thought to be driven almost exclusively by human activities, primarily fossil fuel burning and deforestation, and thus cannot be blamed on natural forces.

Fourth, despite these expected changes there doesn't appear to be a simple solution to the problem. Although technologists are working on extracting this excess gas out of the atmosphere and storing it in salt mines or at great ocean depths, this cannot be done so simply. Growing trees or adding iron pellets to the ocean to stimulate carbon-thirsty plankton growth does not solve the problem either. Likely a solution will be found by reducing our dependence on fossil fuel energy sources which are by far the largest contributor to excessive atmospheric greenhouse gas concentrations.

Finally, many scientists would forcibly argue that we humans may be solely responsible for the alteration of global climates to an extent that may strongly cause a rise in mean global sea level, quicken infectious disease proliferation, disrupt ecosystem stability, raise extinction rates, and, perhaps most pernicious from a anthropocentric point of view, exacerbate world wealth and health disparities. In fact, the Intergovernmental Panel on Climate Change (IPCC), an international group of some 2,500 scientists assembled in 1988 by the United Nations General Assembly and directed to gather and review information on climate change, concluded in 1995 that continued emissions of greenhouse gases would have a dangerous impact on global climate systems, an impact that could result in environmental, economic, social and political risks.

One-hundred and two Nobel-laureates in 1997 signed the World Scientists' Call For Action which sounded the warning that, "Human activities inflict harsh and often irreversible damage on the environment and on critical resources. If not checked, many of our current practices put at serious risk the future that we wish for human society and the plant and animal kingdoms." It is proclamations like these that are motivating many nations to seriously consider reductions in greenhouse emissions via, among other things, a switch from fossil fuel energies to renewable energies, in the form of wind power, solar power, and geothermal (i.e., earth heat) sources.

To summarize, our world faces a tremendous challenge over the next 50–100 years. While our earth is a very fit temperature for human dominance, it is just this dominance that may get the best of us by way of a more energetic (i.e., higher temperature) and unstable environment.

All the aforementioned greenhouse gases have concentrations much less than 1 percent (or equivalently, 10 parts-per-thousand) yet they have this incredible ability to disrupt life as we know it, at a blink of an eye on geologic time scales. We humans must quickly come to terms with the incredible power of these sparse gases before greater harm and damage is realized. **One percent cannot be overlooked because, if it is, humanity and life itself will have to suffer the consequences.**