GREENHOUSE GAS ACCOUNTING HEATS UP

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There has been extensive media attention recently on the topic of Greenhouse Gas (GHG) emissions and their potential effect on the earth's climate. The rhetoric has ramped up considerably since the term entered the general vocabulary roughly twenty years ago. Some authorities point to the enormous volumes of fossil fuel combustion products released to the atmosphere from anthropogenic (human) activities such as power generation, transportation and manufacturing. Other authorities point out that the earth has always experienced cycles in climate variability and as a natural phenomenon we should expect to see warming cycles. Interestingly, few experts disagree that a significant warming trend is underway. The major debate revolves around the cause of the warming and whether the warming trend will reverse itself or whether systems are being set up that will cause the trend to continue upward. This discussion might be relegated to an arcane scientific debate were it not for the fact that the causes and consequences point toward a change in life as we know it if the wrong answer is selected. So which analysis is correct?!

What is the Greenhouse Effect and What are GHGs?

In order to address the question it might be helpful to provide a brief tutorial on the greenhouse effect and greenhouse gasses. The "greenhouse effect" in simplistic terms is caused by certain gases in the earth's atmosphere that allow the energy from sunlight's incoming short wavelength (ultraviolet) radiation to pass but absorbs a portion of the long-wave (infrared) radiation that is reflected after the sunlight strikes earth. This results in additional heat energy remaining in the atmosphere and being re-emitted back to earth. The greenhouse effect is a completely natural phenomenon and is a critical factor in the development of life on earth. Without it, the earth's surface would be too cold to support life as we know it. The key issue is that the heat level (temperature) in the atmosphere seems to be rising at a more rapid rate than expected and threatens to upset a number of key environmental and ecological systems.

That being the case, what are the gases that contribute significantly to the greenhouse effect? In order of abundance, the greenhouse gases are water vapor (H_2O), carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), ozone (O_3), and chlorofluorocarbons (CFCs). Of these gases, those that are considered "anthropogenic" are CO_2, CH_4, N_2O, and CFCs. These are the gases over which humans exercise significant influence with respect to their discharge into the atmosphere, and are the gases covered in the Kyoto Protocol. It is useful to note that CO_2 is not the only greenhouse gas of interest, and it is of key interest due to the volume emitted and some characteristics that will be sketched below.

A Brief History of the GHG Theory

Although the GHG concept has only risen to the public consciousness in recent years, its genesis is over 150 years old. The phenomenon was initially postulated in 1824 by Joseph Fourier in that he noted that energy in the form of visible light from the sun easily penetrates the atmosphere to reach the surface and heat it up, but heat cannot so easily escape back into space. (Fourier is most commonly known as the mathematician who developed the Fourier series, which he applied to the solution of heat transfer problems.) British physicist John Tyndall was interested in the unproven concept, and in 1858 was the first to provide experimental evidence that a greenhouse effect does exist. In 1896, Svante Arrhenius was the first to provide a theoretical basis for GHG activity and further proposed the concept that, as human activity results in increasing release of CO_2 to the atmosphere, the temperature of the globe will also increase. (Yes…this is the same Arrhenius that developed the Arrhenius definition of acids and the Arrhenius rate equation encountered in freshman chemistry.) The concept lay dormant for almost 50 years until Guy Chapman published a paper of his findings that the atmospheric CO_2 levels had increased by 10% since the 1890s. Up to this point in time the greenhouse effect was not considered to have negative connotations because it was believed that the oceans would absorb the vast majority of CO_2 buildup, so his paper was largely ignored. Then, in 1956, Gilbert Plass published a paper based on the results of a computer program that he had developed. It analyzed CO_2 and seawater absorption characteristics to show that adding CO_2 to the atmosphere would, in fact, cause a temperature rise. Although his computer model was a much-simplified version of nature, it indicated that a doubling of background CO_2 levels would result in a 3.6°C rise in surface temperature. The other startling result of his computations was that water vapor would not mask a CO_2 effect. At that point, Dr. Charles Keeling began his measurements of CO_2 at the Mauna Loa Observatory in Hawaii. The Scripps Institute monitoring record continues to the present day and is one of the primary data sources documenting the steady CO_2 rise over the last half-century.

The most recent plot of the data is provided as Figure 1 (source: Scripps Institute of Oceanography/CO_2 program).

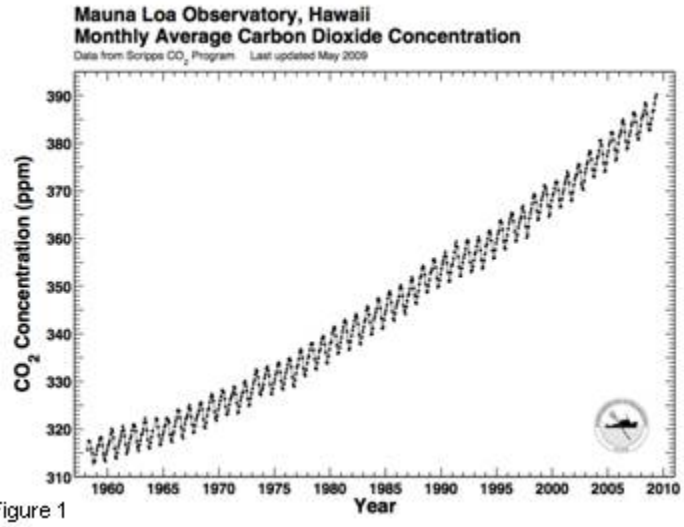

Figure 1

So What?

This might be an interesting scientific investigation, but who cares that CO_2 levels are rising and what does that have to do with our day-to-day lives? Two key components of the scientific and political debate revolve around the concepts of **radiative forcing** and **climate feedback**. Radiative forcing is the term associated with a change in the earth's radiative balance. Several definitions and variants are possible (e.g., direct radiative forcing, indirect radiative forcing, adjusted radiative forcing, instantaneous radiative forcing, etc.), but the concept involved is an attempt to identify and measure factors that influence the sun's irradiance and the energy balance (general units are in W/m^2). Radiative forcing can be positive or negative. These perturbations are caused by such things as volcanic eruptions, solar variation (e.g., sun spot occurrence), changes in radiatively active species concentrations (e.g., CO_2, aerosols) and changes in the reflective properties of the earth or its atmosphere.

Climate feedback is an internal climate process that increases or decreases the climate response to an initial forcing. In other words, it is a process that reinforces or dampens the radiative forcing. As a brief aside it is probably helpful to note the difference between climate and weather. Weather is the short-term day-to-day mix of temperature, humidity, precipitation and wind experienced in a particular location. Climate is the characteristics and processes that control weather in a particular area of the globe. It can also be considered the long-term average and variability of weather in a particular location.

The key point here is that radiative forcing and climate feedback can enhance or adversely affect the environment or ecology we experience. It is important to note that natural and/or human processes can cause the resulting effects. In addition, the feedback mechanisms can be influenced initially by one cause but reinforced or dampened by another. This leads us to the primary cause of the fierce debates.

Difficulty in modeling these processes

To tease out the "cause" of the global warming requires theoretical and empirical analyses that are incredibly difficult. Each factor is typically characterized by complete spatial and temporal variability that is then compounded by interaction with other factors that exhibit the same variability. The physics and chemistry of GHGs on atmospheric radiation are fairly well known and reasonably quantifiable. The controversy centers primarily on the fact that it is difficult to extract a completely unambiguous greenhouse gas warming signal from the climate record. This is not completely unexpected because the time scale of the climate record is quite limited when compared to the recent rise in GHG levels. In what may be one of the great ironies of the topic, a significant complicating factor ostensibly arises from the aerosols circulating around the globe. Aerosols can influence climate by altering cloud formation and reflectivity, as well impacting solar radiation absorption and reflectivity, which mask the warming effect of GHG. The aerosols result in large part from the air pollution generated in the industrialized world. Consequently, as air pollution regulations reduce air pollution emissions, some researchers hypothesize that the global warming may increase because of loss of those aerosols!

In recognition of the difficulty and uncertainty associated with the measurements and computations, the Intergovernmental Panel on Climate Change (IPCC) has adopted a ranking scheme to indicate the level of confidence associated with the various projections they make. A common basis of comparison of various models and scenarios is to use a doubling of the pre-industrial atmospheric CO_2 levels (indicated as 2 x CO_2). While no source is completely unbiased, the IPCC presentation of data and findings are represented as being objectively based. Also, due to the complexity of the modeling undertaking, absolute statements on either side of the debate should be viewed with caution. The magnitude of the risk, though, demands a precautionary approach to the topic.

The way forward

In summary, there appears little doubt that global temperatures are rising and significant changes in global climate patterns are occurring. While natural processes create an ebb and flow of temperature ranges over time, emerging evidence indicates that anthropogenic sources are a significant contributor, if not a driver, of this trend. Public thinking on the topic tends to be too linear. A proper view should consider the interplay of causes and feedback loops. In other words, this is not a chain, but a web of causes. For example, increased forest fire activity generates considerable CO_2 emissions. What proportion of the wildfire activity is natural and what proportion might result from slight changes in precipitation or temperature aggravated by human GHG loads? The key point is that there is less and less likelihood that this is primarily a natural cycle that will shortly reverse itself resulting in a rapid cooling trend (although it should be noted that some credible authorities do assert this).

As if the problem isn't complicated enough, the solution must be mediated through an economic and political process. Indeed, the issue lies at the intersection of fundamental drivers of society. The economies of all of the world's developed societies are based on energy derived from the combustion of fossil fuels. Thus, dictating rapid curtailment of its use could cripple the economic viability of a country and potentially result in social unrest, if not anarchy. Politically, this is an unacceptable solution. Yet, inaction at this point is not a prudent option either, as the more GHGs emitted, the greater the potential long-term effect on our environment. Further complicating matters, this problem does not present itself at a calm point in history. Other serious issues are competing for governmental and business leaders' attention, such as healthcare reform and recovery from a severe global economic crisis, as well as ongoing geopolitical unrest in the Middle East and Korea. These are all enormously important issues that must be competently addressed in a short period of time.

The House of Representatives did pass the Markey-Waxman bill by a slim 219-212 margin, and it has now moved to the Senate for consideration. It's difficult at this point to tell if this is a good piece of legislation, and that probably depends on how one defines "good." A key deadline looms, however, in that the United Nations Copenhagen Climate Conference is to be conducted in December of this year. This conference will debate the extension and modification of the Kyoto Protocol. If the United States expects to have any input into that worldwide body, it must develop a coherent policy to prior to that meeting.

In the meantime, a number of socially responsible businesses are moving ahead with voluntary sustainability initiatives that include GHG accounting measures to reduce their carbon footprint. Larger corporations such as Pepsico, Walmart, and others are, in turn, requiring their vendors and trading partners to take steps to reduce their carbon footprint and GHG emissions as a prerequisite to conducting business with them. In conjunction with this activity, a number of voluntary reporting guidelines and carbon trading schemes have developed. The remarkable thing about this effort is that, in many cases, it has been discovered that hidden savings can reduce the economic burden that was initially projected.

It remains to be seen how much progress can be made to reduce the GHGs in the atmosphere and the associated climate change, but you can be sure to hear much more about ways to reduce GHGs at all levels of society. Considerable effort is necessary to reshape our energy practices and sources while maintaining our standard of living. It may be that new technologies can be developed to sequester or convert CO_2 to other compounds to remove it from the atmosphere. If so, this must be done in a reliable and sustainable manner. The most effective technology would be one that could absorb the CO_2, utilize the carbon, and emit the oxygen back to the atmosphere. We, in fact, currently have such a technology…it is called a tree. It is not likely that any program or set of policies will be successful if a major component doesn't include a reduction in clear cutting of the global rainforests and an increase in reforestation of older areas. It has been estimated that it takes 800 mature pine trees to offset the current carbon footprint of each American. A little reflection on the implications of that statistic is sobering.

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