

The Atmosphere

Introduction

Greenhouse Effect/Climate Change/Global Warming

The terms "Greenhouse Effect", "Climate Change", and "Global Warming" are often used interchangeably, yet they really refer to three separate and distinct processes. In this section, we'll examine all three and assess whether the earth's atmosphere is getting warmer.

To begin with, let's look at how the Earth's atmosphere is heated. The energy that heats the atmosphere comes from the Sun, and the Sun is a huge source of energy, so large that it is difficult to understand in human terms, but let's try. The sun generates about 5.6 x 10^{27} calories of energy every minute. A calorie is the amount of energy required to raise the temperature of one gram of water one degree centigrade. Ten to the 27th power is a big number, ten octillion, to be exact. Ten octillion is ten billion, billion...billion. Another way to get a perspective on the size of this number is to compare it to global financial data, for which you might have a better intuitive sense. The estimated total value of the whole world's stocks, bonds, securities, and other financial assets is \$50 trillion, or 10^{12} dollars. So you can see that 10^{27} is a way huge number. Keep in mind that the Sun generates this amount of energy every minute.

Though the sun transmits energy in various wavelengths, most of the Sun's energy is transmitted in wavelengths of between 700 to 400 nanometers, the spectrum of visible light. Energy emitted from the sun travels at the speed of light, which is 186,000 miles per second or 11,160,000 miles per minute, way faster than any red convertible you'll see on the interstate. Since the distance between earth and sun ranges from 91,500,000 to 94,500,000 million miles and averages 93,000,000, it takes about $8\frac{1}{2}$ minutes for the sun's energy to reach earth.

The sun sends its solar radiation out into space and the earth intercepts only a small portion of it, about one part in two billion. Yet one part in two billion is a tremendous amount, some $173,000 \times 1015$ watts per year. About ½ of the sun's energy that reaches the earth's atmosphere is reflected back out into space and about ½ reaches the surface either directly as visible light or indirectly as scattered light. Once the sun's energy reaches the earth's surface, it is absorbed and the temperature of the earth's surface increases. The surface then begins to emit radiation in the form of infrared or heat energy, which has a longer wavelength than light energy.

Water vapor, carbon dioxide (CO2), and methane (CH4), 3 of the gases among the many that make up the atmosphere, allow sunlight to pass through easily, but absorb infrared heat, or thermal, energy released by the earth's surface. As this absorption takes place, the earth's atmosphere is warmed. We can't see this absorption taking place, but we know that it does, in the same way that solid surfaces, such as dirt and concrete, absorb light energy, or a sponge absorbs water. Water vapor, CO2, and CH4 are not the only gases, which are efficient absorbers of heat energy. Nitrous oxide (N20), also known as laughing gas, chlorofluorocarbons (CFCs) and hydrocholorfluorocarbons (HCFCs) as well as a few other synthetic compounds, also trap infrared energy emitted from the earth.

The ability of the earth's atmosphere to allow the passage of visible light, but absorb reradiated heat energy emitted from the earth's surface is known as the greenhouse effect. Though there are relatively little of these greenhouse gases in the atmosphere, less than 1% of the atmosphere's total volume, these gases are responsible for heating the atmosphere. This absorbed atmospheric heat is what we feel at the surface. The global average surface temperature on earth is about 15°C, about 59° Fahrenheit. The average surface temperature of the moon, which is roughly the same distance from the sun as the earth,

is about -18°C, about 0° Fahrenheit. The reason why the moon is so much colder is because the moon does not have an atmosphere, and therefore no greenhouse gases to trap extra heat. If there were no greenhouse gases on earth, our average surface temperature would be roughly the same as that of the

moon.

Eventually all the heat that is absorbed by the earth's greenhouse gases is returned to space. We know this because the earth's atmosphere would continue to heat up if this energy was not released back into space. So, greenhouse gases really just slowdown or delay the outward transmission of heat from the earth's surface. The slower the transmission, the warmer it is near the surface. To get a better sense of how this transmission of heat works, think about what the sky looks like on the coldest winter nights. The coldest nights are always the clearest because there is little or no cloud cover to capture heat being released outward from the surface. Similarly, those places with the hottest days and coolest nights are locations with the least amount of cloud cover, such as deserts.

Weather refers to the daily conditions in the atmosphere. Climate is the long-term average conditions. We know that the earth's climate has changed over the

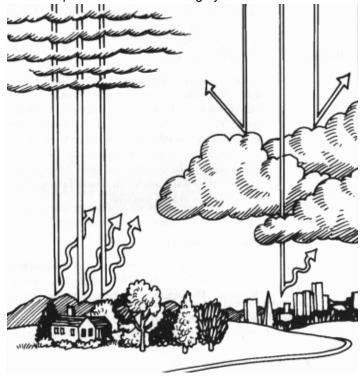


Fig. 1: Diagram of radiation in the atmosphere (NASA)

millennia due to many factors. These include variations in the sun's output, changes in the earth's orbit and tilt, and volcanic activity. These natural variations in the earth's climate are known as climate change.

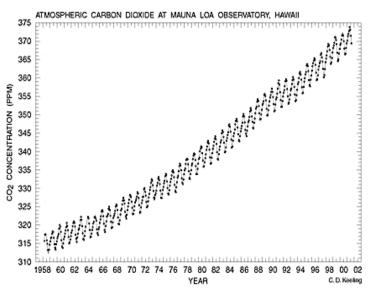


Fig. 2: Yearly CO2 Observations (NOAA)

So far we've defined two of the three terms we started with. Now let's look at global warming. Global warming refers to the human or anthropogenic "enhancement" of the ability of the earth's atmosphere to absorb outgoing thermal energy from the earth's surface. Over the last 150 years, human activities, most notably the burning of fossil fuels such as coal, petroleum, and natural gas, have released large quantities of "greenhouse" gases, such as carbon dioxide and methane. These accumulating amounts of greenhouse gases are slowing changing the chemical composition of the global atmosphere, as well as the atmosphere's radiative, or heat absorbing, properties.

Scientists believe that in 1860, the global atmosphere contained 288 parts per million of carbon dioxide. Recent measurements (Figure 2) indicate that the atmospheric

concentration of CO2 is now 370 parts per million, a relative increase in the amount of atmospheric carbon dioxide of 28%. The reason that 1860 is used as the base year for greenhouse gas concentrations

is that large scale industrialization, driven mainly by coal powered steam engines, did not get off the ground until after 1860. The pre-1860 atmosphere, therefore, is considered to be representative of the atmosphere in its "natural" state.

The pre-industrial concentration of methane was 848 parts per billion (ppb). Atmospheric concentration in 2001 was about 1800 ppb, a relative increase of over 100%, or a doubling of the atmospheric concentration. The current atmospheric concentration of nitrous oxide is 315 parts ppb, a 10% increase over the 1860 concentration of 285 ppb. The synthetic greenhouse gases, CFCs, HFCs, PFCs, and SF6, were not present in the pre-industrial atmosphere at all. Current levels of chlorofluorocarbons are 533 parts per billion, HFCs at 154 parts per trillion (ppt), PFCs at 79ppt and sulphur hexafluoride at 5 ppt.

Slowly, the ability of the earth's atmosphere to absorb heat from the surface has increased and, with it, the temperature of the atmosphere. This is known as global warming. So, given that we know that the atmospheric concentration of greenhouse gases has increased, is the earth getting warmer? Let's take a look.

In December 2003, the American Geophysical Union (AGU) stated, "Scientific evidence strongly indicates that natural influences cannot explain the rapid increase in global near-surface temperatures observed during the second half of the 20th century". The AGU is a membership society of some 41,000 individuals from over 130 countries uniting Earth, atmospheric, oceanic, hydrologic, space, and planetary scientists. The AGU now joins the American Meteorological Society (AMS), the National Research Council (NRC), the World Meteorological Society (WMO) and the Intergovernmental Panel on Climate Change (IPCC) in stating that human activities are altering the chemistry of the atmosphere resulting in a warming of the lower atmosphere.

In January 2001, the Intergovernmental Panel on Climate Change reported that:

- * The Northern Hemisphere temperature rise since 1900 is the most of any century for the past 1,000 years.
- * Duration of lake/river ice in the Northern Hemisphere has shortened by about 2 weeks since 1900.
- * Artic sea-ice thickness during late summer and early fall has declined 40% in recent decades.
- * Snow cover in the Northern Hemisphere, has decreased by about 10% since the late 1960s.
- * The 1990's were the warmest decade since record keeping began in 1861.
- * 1998 was the warmest year since record keeping began in 1861.

In December 2001, the World Meteorological Society reported that:

- * nine of the ten warmest years on record since 1861 occurred in the 1990s, and that;
- * the rate of global temperature increase tripled during the 20th century.

On January 15, 2004, the National Oceanic and Atmospheric Administration's (NOAA) reported the following:

- * Since 1900, global surface temperatures have increased at a rate near 1.0° F/Century (0.6° C/Century);
- * The rate of warming of the atmosphere has increased by a factor of three since 1976;
- * 2003 tied 2002 as the second warmest year in the meteorological record, and;
- * the 10 warmest years have all occurred since 1990.

References

1 http://www.un.org/reports/financing/profile.htm

ESA21: Environmental Science Activities

Activity Sheet Climate Change

Student Name:

Professor Name:

Climate Change - Activity Sheet

Global warming is a huge issue, not just because of the potential impact of the warming on the earth's ecosystems, but also because the principal activity responsible for the bulk of emissions, fossil fuel combustion, literally fuels the engines of industrialized, urbanized societies. The stakes are huge -- international, political, financial, and environmental. In this exercise, you'll learn about how to assess information sources, a critical skill in forming your own opinions and actions.

Part One - IPCC Overview

Recognizing the problem of potential global climate change the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP) established the Intergovernmental Panel on Climate Change (IPCC) in 1988. The IPCC's function is to assess "on a comprehensive, objective, open and transparent basis the scientific, technical and socio-economic information relevant to understanding the scientific basis of risk of human-induced climate change". The IPCC is composed of three working groups, each charged with a different task. Group One, known as the Science Working Group is charged with assessing scientific aspects of climate change and global warming.

The IPCC Science Working Group has issued 3 summary reports assessing the global climate, in 1990, 1995, and 2001. If you go to the IPCC website, you'll find that over 150 delegates from about 100 governments participated in the working group meetings leading up to the 2001 Third Assessment Report. The report, which took three years to produce, is over 1,000 pages in length, and was written by 123 lead authors, and assisted by 516 contributing authors. In addition, the Third Assessment Report incorporated the findings of the two previous reports released in 1990 and 1995. In the 2001 report, Working Group One projected that the earth's globally averaged surface temperature would increase between 1.4 to 5.8°C (2.5 to 10.4°F) by the year 2100.

Part Two - Science Discussion Forum

Some months after Working Group One released the Third Assessment Report, in the July 20, 2001 issue of the journal Science, there was a discussion forum involving two groups of scientists about whether the mathematical analysis conducted by the IPCC, upon which it's projection of future climate change is based, was sound. Review both articles and answer the following questions.

Article – One (Uncertainty in the IPCC's Third Assessment Report - by Myles Allen, Sarah Raper, and John Mitchell)

Article – Two (Uncertainty and Climate Change Assessments - by John Reilly, Peter Stone, Chris Forest, Mort Webster, Henry Jacoby, and Ronald Prinn)

1. In your own words, provide a brief summary of both of the articles in a short paragraph or two. a. Uncertainty in the IPCC's Third Assessment Report - by Myles Allen, Sarah Raper, and John Mitchell (Team One).
b. Uncertainty and Climate Change Assessments - by John Reilly, Peter Stone, Chris Forest, Mort Webster, Henry Jacoby, and Ronald Prinn (Team Two).
 At the conclusion of each of the articles, there is information about the organizations and institutions that each of the scientists are from. Copy this information from the article to the space provided below. Team One - Myles Allen, Sarah Raper, and John Mitchell

b. Team Two - John Reilly, Peter Stone, Chris Forest, Mort Webster, Henry Jacoby, an Ronald Prinn
3. Based on the description of the organizations and institutions provided, in your judgmen is there any qualitative difference between the two groups in terms of their scientific credibility and credentials? If so, why?
4. If you had to pick one of the two groups as being more "expert", which group would you pick and why?
5. Has reading the two articles affected your "faith" in the IPCC process or its conclusions Please explain.

Part Three - Information Evaluation

A critical part of scientific inquiry is assessing information sources. So far in this exercise, you've reviewed two articles and checked on the backgrounds and expertise of both groups, and reached a conclusion about which group you feel is more "expert" as well as which one you place your "faith" in. However, things aren't always as they seem, and sources of information, even from prestigious academic institutions, need to be carefully checked before reaching any final conclusions. So, let's look a little closer at both groups.

To begin with, go to http://www.awi-bremerhaven.de/index-e.html . Review the main page, and then click on the link entitled "About Us".

and then click on the link entitled "About Us".
6. Describe how Team One is funded.
7. Has your assessment of the scientific credibility of Team One changed at all now that you've done an assessment of their funding sources?
Let's take a closer look at Team Two. Go to http://web.mit.edu/globalchange/www/ and
review the main page. Then, check on the "sponsors" link in the left hand menu column.
8. Describe how Team Two is funded.

9. Has your assessment of the scientific credibility of Team Two changed at all now that you've done an assessment of their funding sources?
10. How do you feel about the two teams now? If you had to pick one team as being more scientifically credible, which team would you pick and why?
11. How do you feel about what you've found out about the differences in funding between the two groups?
In summary, the global warming issue is going to be front and center of the scientific community for a long time. As we learn more about the earth's climate system and how it is changing, policy makers, institutions, organizations, and corporations will continue to be actively involved in the debate. As a means of objectively discerning scientific consensus versus other agendas, it is imperative to learn how to critically evaluate sources of information.