The Carbon Cycle – The Annual Greenhouse Gas Index

Category

Science, Mathematics, Reading

Materials

Annual Greenhouse Gas Index (Included)

Real World Connection

Research, Future Planning, Commerce, Climate, Transportation

Problem Questions

How can data be presented so that people understand whether or not the Earth's atmosphere is warming?

How has the radiative heat balance of greenhouse gases in Earth's atmosphere changed since 1978?

Prior Knowledge What I Know Based on your prior knowledge, answer the problem question to the best of your ability.	Conclusion What I Learned Answer the problem question after completing the activity.
1. 2.	1. 2.

Background

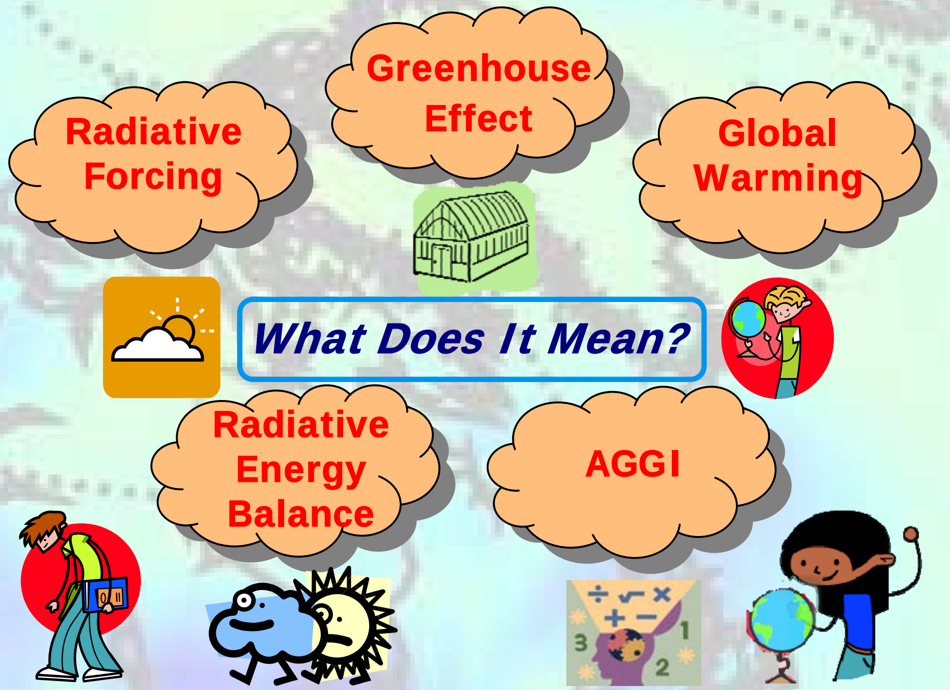
Researchers want to help students and adults to understand Earth and how it is changing. In this case, the topic is global warming.

Scientists at the National Oceanic and Atmospheric Administration came up with...

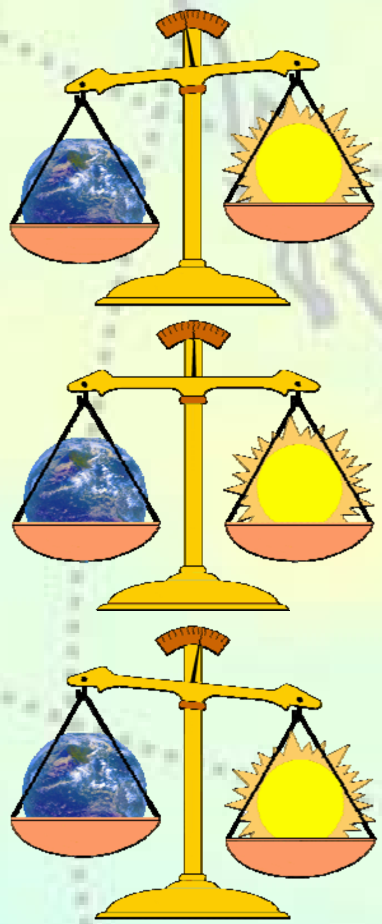
AGGI (pronounced ah-gee),

one number that combines data from natural sources and human activities to answer the basic question, “How much will Earth’s atmosphere warm?”

Here is the story.

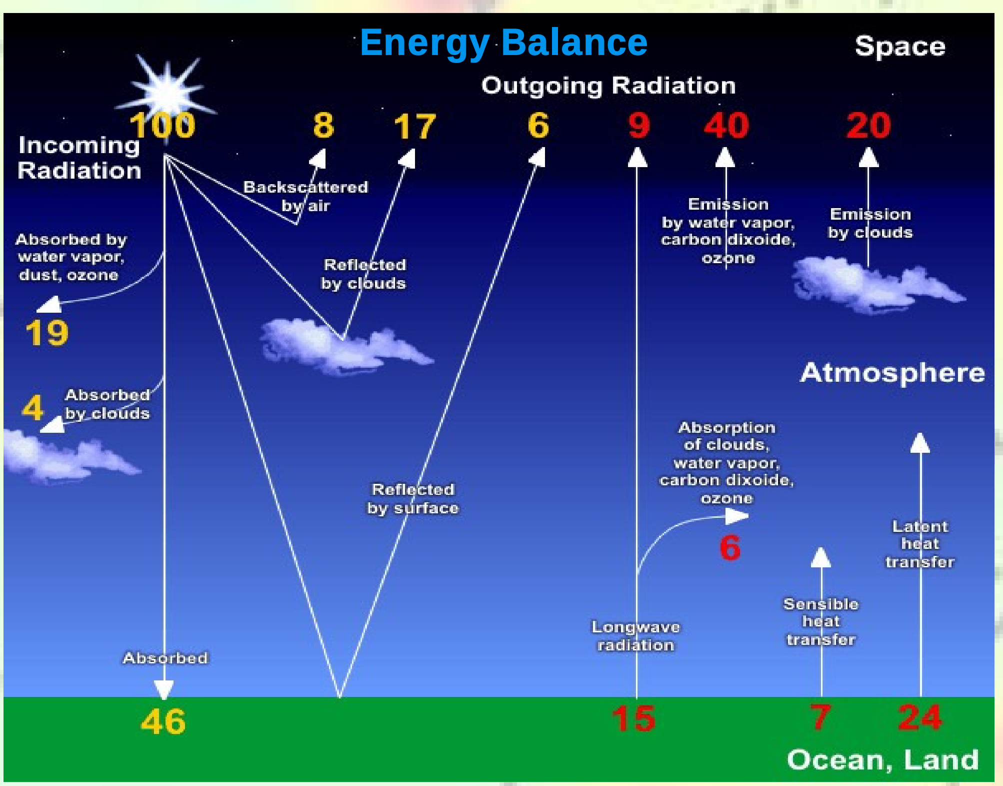


Like two objects trying to balance on a scale, solar radiation from the Sun and infrared radiation from the Earth seek a balance.



When Earth's Atmosphere Is Like A Kitchen

To understand the interaction between natural causes and human influence on global warming, an ordinary kitchen stove serves as an example. About the stove, ask, "How far have we turned the dial on the stove?.“ When you turn the burner on high, the burner is not instantly hot, even though the electricity supply to the burner is at full strength. It takes time for the system to respond. Likewise, our atmosphere and oceans does not respond immediately. If we added no more carbon to the system, beginning immediately, Earth‘s atmosphere would continue warming.



Background (Continued)

Energy Balance

When the incoming energy from the Sun and outgoing energy from the Earth is balanced, Earth's temperature is steady and the climate is stable.

Energy that controls Earth's weather and climate comes from the Sun. Normally, there is a balance between the amount of energy that is absorbed by Earth from the Sun (solar energy), and the amount of energy radiated back into space (infrared energy) from Earth. This normal energy balance of solar and infrared "radiation" can be upset – or "forced" to change. Thus, a measure of how Earth's radiative balance is being pushed or forced away from normal is called "radiative forcing".

Radiative forcing is not a direct measurement, but is a calculation using the amount of each greenhouse gas in the atmosphere and its ability to retain heat. A positive radiative forcing means that Earth's surface has a tendency to warm and a negative radiative forcing tends to cool.

Energy Balance Interrupted

As fossil fuels burn, both energy and carbon dioxide (CO_2) are released. Over time, the amount of carbon dioxide builds up in Earth's atmosphere, where it absorbs more infrared energy that would normally be radiated back into space. Careful measurements for the past half century show that carbon dioxide has been accumulating in Earth's atmosphere at an increasing rate. When the carbon dioxide concentration builds up, the energy balance in Earth's atmosphere is interrupted and average global temperature rises. Acting like a blanket covering Earth, carbon dioxide traps infrared energy causing the greenhouse effect.

Major Greenhouse Gases

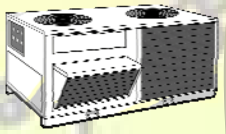
Five major greenhouse gases account for 97% of the unbalanced heating of the Earth's atmosphere. The remaining 3% is due to a molecules called halocarbons (refer to page 13-4).

1. Carbon Dioxide (CO_2)

A heavy, colorless, odorless gas present in the atmosphere. Composed of one atom of carbon and two atoms of oxygen. Formed by the burning of fuels containing carbon, exhaled by animals, and used by plants in photosynthesis.

2. and 3. Chlorofluorocarbons (CFC 11 and CFC 12)

Chemical compounds consisting of carbon, hydrogen, chlorine, and fluorine. They are used as aerosol propellants and refrigerants (including in air conditioning), and also in making styrofoam.



4. Nitrous Oxide (N_2O)

A by-product of fertilizer used in agriculture, such as on a wheat or corn field.

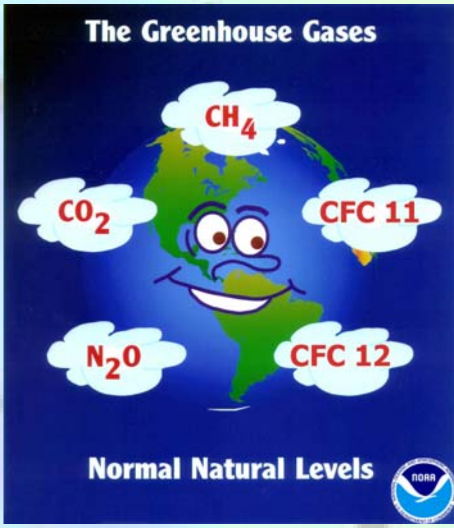
5. Methane (CH_4)

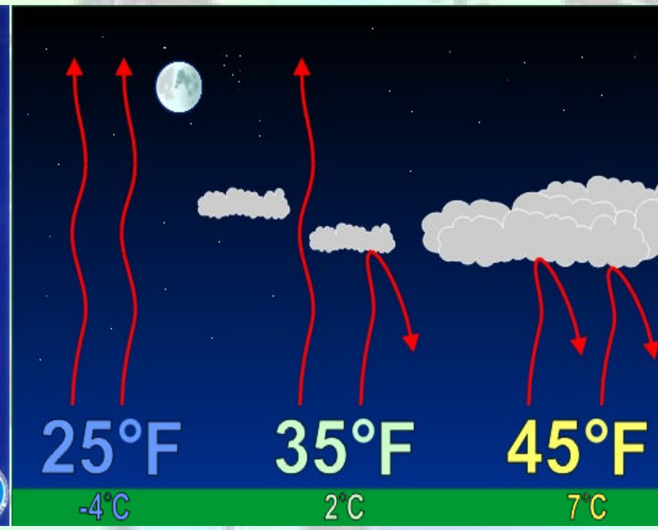
An odorless, colorless, flammable gas that is the major part of natural gas. It can be formed from rotting organic matter and animal waste and is used as a fuel.

Background (Continued)

Halocarbons

A group of gases containing the following... carbon, chlorine, fluorine, and iodine.





A Natural Greenhouse Effect

Without a natural greenhouse effect, the average temperature of the Earth would be around **0°F (-18°C)** instead of its present **57°F (14°C)** .

So, the concern is not with the fact that we have a greenhouse effect, but whether human activities are leading to enhancement of the greenhouse effect.

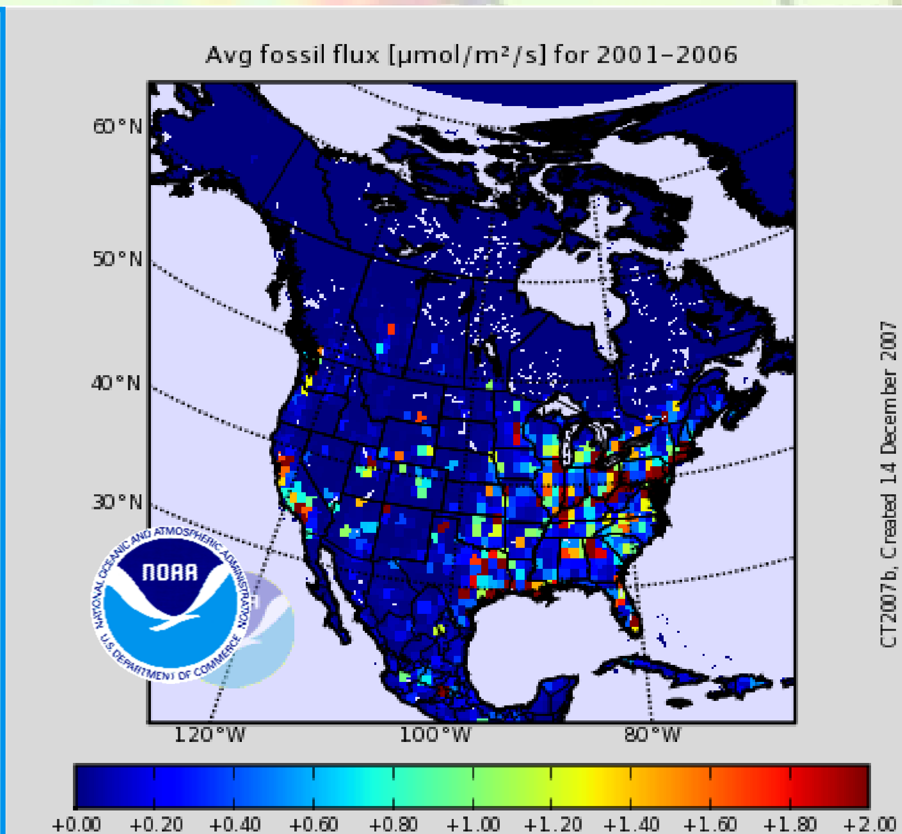
Notice where in North America carbon dioxide is given off as a result of burning coal, oil, and gas. In other words, notice where the numbers are higher in the figure on the lower right.

Researchers track carbon being given off (**sources**) and taken in (**sinks**) to determine the effect on Earth's energy balance. Together, sources and sinks are move **CO_2** to and from the atmospheric **carbon reservoir**.

When the earth **absorbs more radiation** than it emits to space, the atmosphere and oceans will warm.

A new balance will be established when the earth and atmosphere have warmed enough to once again give off exactly the same amount of energy to space as it absorbs from the sun.

This happens because any object always emits more radiation when it is warmer than when it is colder.



Background (Continued)

Think About This...

Earth's energy balance is important because it determines Earth's average temperature, and therefore, affects our climate. List examples of how a change in Earth's energy balance might affect us.

So...how can data be presented so that most people understand whether or not the Earth's atmosphere will be forced to warm?

Easy!

1. Create a **scale** that uses the number one as a baseline.

2. Call the new scale by an easy name to remember – **AGGI (pronounced "AH-GEE" Annual Greenhouse Gas Index)**.

3. Let a **positive AGGI** mean that Earth's surface has a tendency to **warm**, while a **negative AGGI** means that the Earth's surface has a tendency to **cool**.

4. **Recalculate** the new scale once a year to keep current.

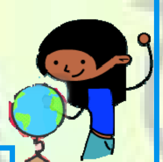
For example, the **AGGI** for 2004 is 1.198, which means that climate forcing in 2004 was 1.198 times as strong as (or 19.8% stronger than) in 1990. Since the **AGGI** number is **positive**, Earth's atmosphere **warmed** in 2004.

FYI - The AGGI (Optional)

How was the AGGI developed?

Researchers at NOAA's Earth System Research Laboratory developed a system called the **Annual Greenhouse Gas Index (AGGI - pronounced Ah - Gee)**.

The **AGGI** is a **ratio**. The climate forcing caused by the sum of all long-lived greenhouse gases in any given year divided by the climate forcing in 1990. The ratio is a pure number with no units. The **AGGI** for 1990 equals 1.000 because climate forcing in that year is divided by the climate forcing in 1990, the same year.



The number for radiative forcing is compared to the number one. If a future **AGGI** value is more than one, the radiative balance is higher than the baseline and Earth's atmosphere is warming; if the AGGI number is less than one, the radiative balance is decreasing and Earth's atmosphere is cooling.

The baseline for the **AGGI** is the radiative forcing of greenhouse gas levels that were present in Earth's atmosphere in 1990 - a year chosen because it is the baseline year for the Kyoto Protocol. In that year, the United Nations started the preparations leading to the U.N. Framework Climate Change Convention which was signed in Rio de Janeiro, Brazil, in 1992.

Procedure – Part 1 – "Fill In Data Table"

Working with data much like a researcher, you will complete the AGGI Table (Table 13-1), then graph the data. Use the directions that follow. Note that rounding-off numbers may result in slight variations.

1. Fill in the column labeled **"Total"** in Table 13-1 by adding the radiative forcing numbers for each gas. The number for each gas is determined by two factors, its increase since the year 1850 and how effective it is when absorbing infrared heat radiation. The first two are done for you.
2. Fill in the **"AGGI 1990 = 1"** column in Table 13-1. Divide each greenhouse gas total by **2.172** which is the total radiative forcing for 1990 and the value used for comparison. The first two are done for you.
3. Calculate the Annual change (%) and enter the value in the **"% Change"** column in Table 13-1. Use the following steps.
   a) Starting with 1979 and 1980, subtract the AGGI for 1979 from the AGGI number for 1980 to find the difference.
   b) Divide the difference from the step above by the AGGI for the earlier year.
   c) Move the decimal point two places to the right. (This is an easy way to divide by 100.) Record the result in the **"% Change"** column. The first one is done for you. Refer to the sample calculation at the bottom of this page for assistance.
   d) Repeat these steps for each pair of years.

AGGI Calculation Sample – 1979 to 1980 Annual Change

Note that rounding-off numbers may result in slight variations.

a) **0.802 (1980)**
0.781 (1979)
0.021 (Difference)

b) **0.021 (Difference) Divided By 0.781 (1979) [0.021/0.781 = 0.0268886]**

c) **0.0268886 → 002.68886 → 2.69%**

Procedure – Part 2 – "Graph the AGGI Data"

1. Using Figure 13-1, on the left-hand (bottom) side of the graph, label this y-axis at the tick marks from 0.0 to 3.0 by tenths (0.0, 0.1, 0.2, 0.3, 0.4 ... 2.8, 2.9, 3.0) for the radiative forcing data from Table 13-1 (each individual gas and total). The first three and last one are done for you.
2. Using Figure 13-1, on the right-hand (top) side of the graph, label this y-axis at the tick marks from 0.0 to 1.4 by 5 one hundreths (0.00, 0.05, 0.10 ... 1.30, 1.35, 1.40) for the AGGI data from Table 13-1. The first three and last one are done for you.
3. Using Figure 13-1, on the bottom (right) side of the graph, label the x-axis with the years, beginning with 1979 and ending with 2006. The first three are done for you.
4. Using a different colored pencils and the y-axis on the left-hand side, graph the radiative forcing for each greenhouse gas and the total from 1979 – 2006. Now using the y-axis on the right-hand side, graph the AGGI (use a bold line).
5. Label both axes of your graph, make a color key and write a title.
6. Extra – if you have access to a computer, use Microsoft Excel to graph your data.

Procedure – Part 1 – "Fill In Data Table"

Global Radiative Forcing 1979 – 2006 (W m^{-2})								AGGI 1990=1	% Change
Year	CO_2	CH_4	N_20	CFC12	CFC11	10 Minor	Total		
1979	1.026	0.412	0.101	0.090	0.039	0.029	1.697	0.781	---
1980	1.056	0.418	0.102	0.094	0.041	0.032	1.743	0.802	2.69
1981	1.075	0.425	0.106	0.100	0.043	0.034			
1982	1.086	0.432	0.109	0.106	0.045	0.036			
1983	1.111	0.438	0.111	0.111	0.048	0.039			
1984	1.137	0.446	0.113	0.116	0.050	0.041			
1985	1.159	0.451	0.114	0.121	0.053	0.044			
1986	1.181	0.456	0.118	0.128	0.055	0.048			
1987	1.209	0.460	0.118	0.134	0.058	0.051			
1988	1.246	0.464	0.122	0.140	0.061	0.055			
1989	1.271	0.469	0.125	0.146	0.063	0.059			
1990	1.291	0.472	0.129	0.153	0.066	0.062			
1991	1.311	0.476	0.131	0.156	0.067	0.064			
1992	1.321	0.480	0.133	0.160	0.067	0.069			
1993	1.332	0.481	0.135	0.162	0.068	0.071			
1994	1.353	0.483	0.137	0.164	0.068	0.072			
1995	1.380	0.485	0.139	0.166	0.068	0.073			
1996	1.407	0.486	0.142	0.168	0.067	0.075			
1997	1.423	0.487	0.144	0.169	0.067	0.076			
1998	1.463	0.491	0.147	0.170	0.067	0.077			
1999	1.494	0.494	0.151	0.171	0.066	0.078			
2000	1.511	0.494	0.151	0.171	0.066	0.079			
2001	1.534	0.494	0.153	0.171	0.065	0.081			
2002	1.564	0.494	0.156	0.171	0.065	0.082			
2003	1.600	0.496	0.158	0.172	0.064	0.084			
2004	1.626	0.496	0.160	0.171	0.064	0.085			
2005	1.655	0.496	0.162	0.171	0.063	0.086			
2006	1.685	0.495	0.165	0.170	0.062	0.087			

Table 13-1. Data Used to Calculate the Annual Greenhouse Gas Index (AGGI)

Procedure – Part 2 – "Graph the AGGI Data"

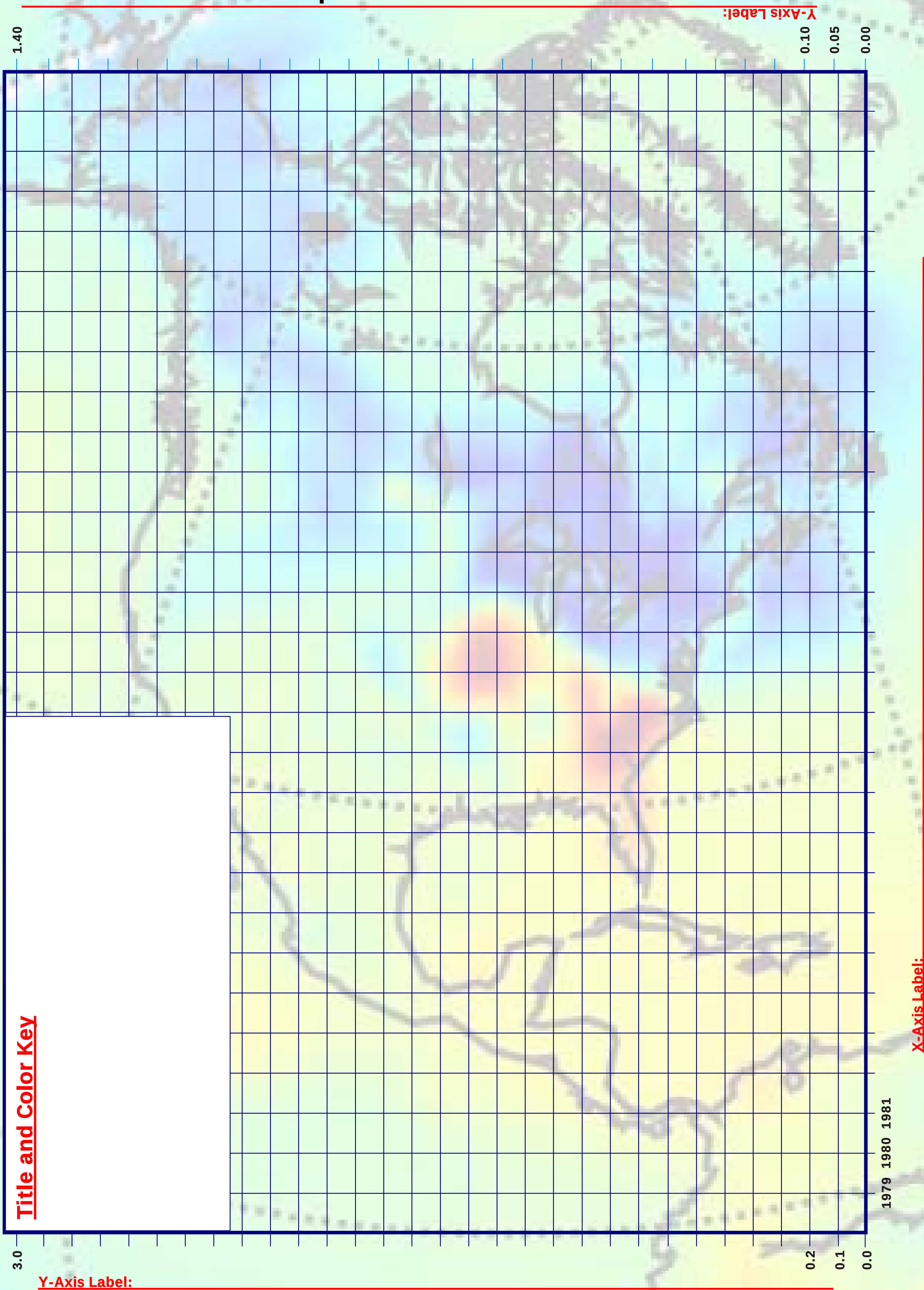


Figure 13-1. Graph for Plotting Radiative Forcing and Annual Greenhouse Gas Index (AGGI) Data

Questions

1. Where does most of Earth's energy come from?

2. What happens to Earth's temperature when the energy in the atmosphere becomes unbalanced?

3. What would happen to Earth's temperature if there were no greenhouse effect?

	Name the five major greenhouse gases.	Write the chemical symbol for each of the five major greenhouse gases.	Write the trend (increasing, decreasing, remain the same) for each of the five major greenhouse gases.
4.			
5.			
6.			
7.			
8.			

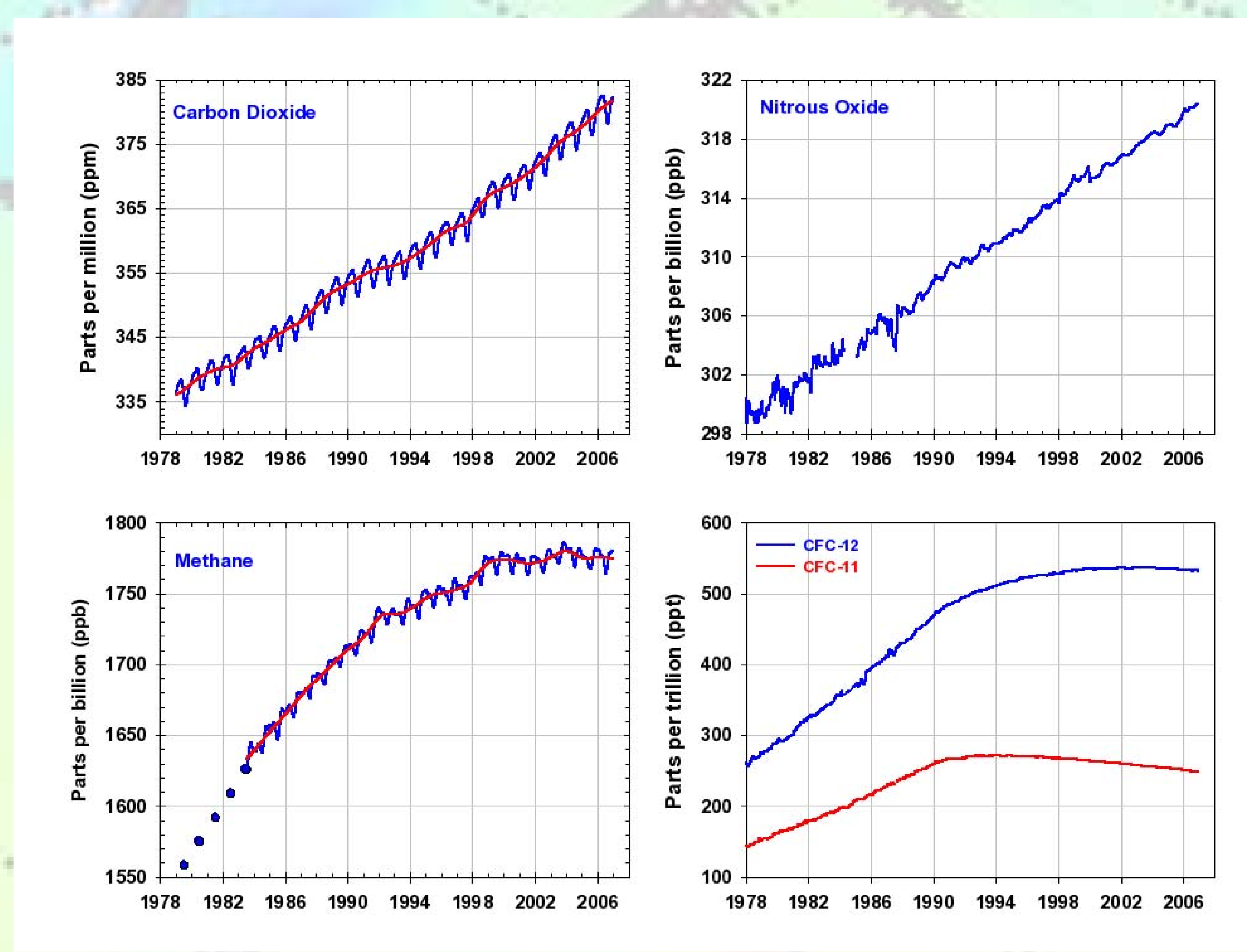
9. Out of the five main long-lived greenhouse gases, name the gases that continue to increase.

10. Name the greenhouse gases that remain approximately unchanged or are decreasing.

11. According to the AGGI, between what two years was the smallest annual change?

Questions (Continued)

12. Which gas has the highest rate of change? (Hint – Use the following global average graphs.)



13. What trend do you see for CFCs?

14. What trend do you see for CH_4?

15. What trend do you see for CO_2?

16. Why is the AGGI an improvement over other scales?

Questions (Continued)

17. What was the AGGI in 2006?

18. According to the AGGI, what percent change (in radiative forcing) occurred between 1990 and 2006?

19. Is the Earth's atmosphere warming, cooling, or steady in 2006? How can you tell from the AGGI?

20. **OPTIONAL:** What year is the AGGI baseline? Why?