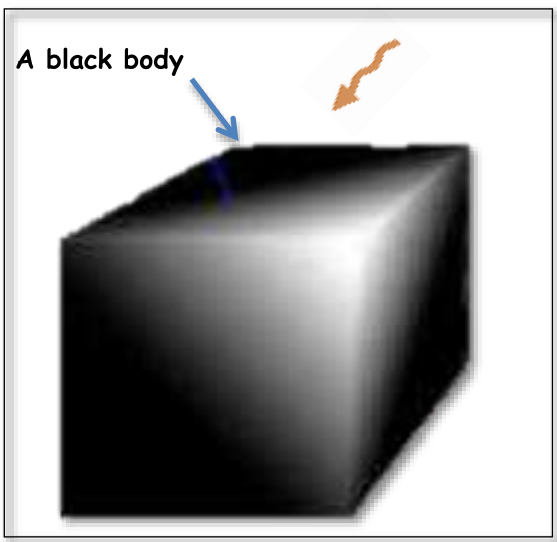
Student Sheet 1

CRITICAL THINKING ACTIVITY:
What is the Earth's the energy budget?

A ***budget*** is a plan that shows how something enters and leaves a system and how much remains in the system. For example, a family budget lists the amount of money coming in (earned), the amount going out (spent) and the amount that remains (savings.) Budget plans can be used for things other than money. Earth's systems are often described in terms of budgets.

The ***energy budget*** of the Earth involves incoming solar energy, outgoing amounts of energy, and the amount of energy that stays in the atmosphere and how the energy flows from one place to another.



There are many different ways to represent the energy balance of the Earth using diagrams. The numbers used in the diagrams are estimates based upon the ***solar constant***, the measure of the average amount of energy that reaches the upper part of the Earth's atmosphere. The amount of energy that reaches the Earth is called ***insolation*** and units of this energy are ***watts/sq.meter/second (W/m2/sec.).*** Think of it as the amount of energy absorbed every second of every day by a pure black, square object that measures 1 meter on a side and is at the top of the atmosphere.

TASK: Use the Introduction and other short reading selections, the diagram of Earth's Energy Budget and the Graphs 1-3 to complete the following activities in Parts 1-3.

Student Sheet 2

PART 1: INTRODUCTION

1. Think about an elevator in a building with 25 floors. Compare the idea of a budget to the up and down motion of an elevator car from one floor to another.
   - ✓ What would the movement of the elevator cart down represent?
   - ✓ What would the movement of the cart upward represent?
   - ✓ What would be the total balance available to the elevator?

2. What factors determine the total energy budget of the Earth?

1. Explain and diagram what the solar constant is.

4. Why is the average amount of solar energy received by the Earth referred to as a "constant"?

PART 2: ATMOSPHERIC ABSORPTION OF ENERGY

1. How much short wave energy comes from the Sun as measured at the top of the atmosphere?

2. What is the total amount of radiation that is reflected by the atmosphere (mainly clouds) and the Earth's surface (land, sea and ice)?

3. What happens to the energy that is not reflected back to space? How much energy is it?

The energy coming from the Earth's surface is in the form of infrared radiation. It results from the heat required to evaporate water and radiation from the Earth in the forms of geothermal heat and heat energy from absorbed insolation that is reradiated.

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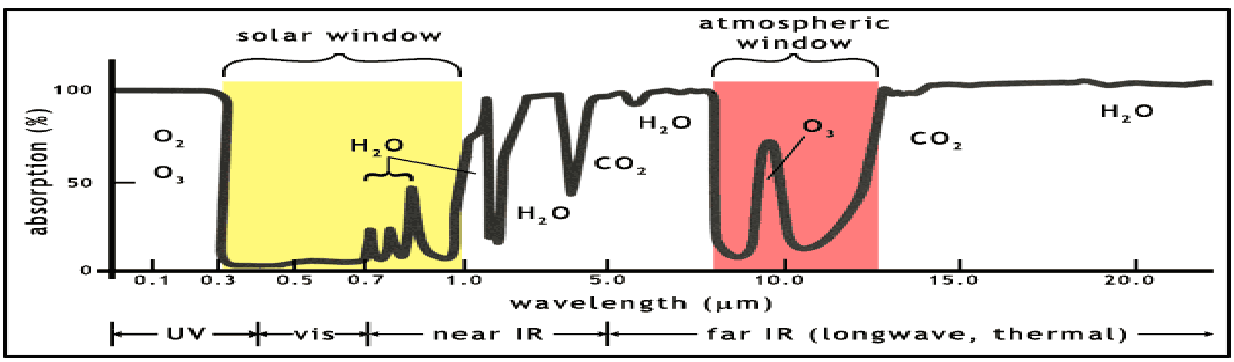
Some of this infrared energy is trapped in the atmosphere by H_2O, CO_2, and O_3, and some passes through to space. Energy that has wavelengths ranging from 7 to 17 micrometers is not absorbed well by H_2O vapor, CO_2 and O_3, and so it passes through the atmosphere and into space. This is known as an atmosphere "window." This "window" is represented by the open space in pink in the diagram below. The top black line (100%) on the diagram represents the maximum amount of energy that could be absorbed in the atmosphere by different gases and wavelengths of radiation. The empty space below the line represents amounts of energy that are not now being absorbed. The diagram shows the regions of the electromagnetic spectrum (light) that are absorbed by specific molecules, but that could be increased if the amounts of certain gases were to increase.

Graph 1: Atmospheric Absorption of Energy



Methane (CH_4) is very good at absorbing energy in wavelengths of 7-17 μm. An increase in CH_4 in the atmosphere can to "close" this window, trapping more heat energy could be trapped in the atmosphere and less radiated into space.

4. Explain how an increased amount of CH_4 in the atmosphere would influence the greenhouse effect and global warming.

5. Which gas absorbs energy at almost all wavelengths?

6. Explain how an increase in the global average temperature would add to the H_2O vapor content of the atmosphere and create a positive feedback loop.

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7. How much infrared energy is radiated into space by the atmosphere?

8. How does the amount of energy entering the Earth's energy budget from space compare with the amount of energy leaving the Earth's energy budget into space?

9. Over long periods of time (years) is the amount of energy entering the atmosphere from space and the amount leaving the Earth's climate system balanced? Explain.

10. If nothing changes within the system, would you expect the average temperature of the Earth to stay the same? Explain.

11. How much energy is absorbed by the Earth' surface (land, ice and oceans)?

12. What is the difference between this amount of energy and the total amount of energy radiated by Earth's surface?

This is the energy returned to Earth or "trapped" by the atmosphere, which is responsible for heating the atmosphere to an average temperature of about 15° C. This is known as the "greenhouse effect". The heat is captured and re-radiated back to Earth by clouds, H_2O vapor, CO_2, O_3, CH_4, N_2O, and CFCs. Without the greenhouse effect part of the climate system, the Earth's surface would be about 33°C cooler than it is now. It would be about the same as the surface temperature of the moon (about $^-18$°C).

13. Why would the Earth with no greenhouse effect have a temperature about the same as the Moon's?

14. Explain what would happen to the Earth's energy budget and the greenhouse effect is the amount of insolation increased?

15. Explain what would happen if the amount of greenhouse gases was to increase.

Part 3: Sunspots and Climate Change

Earlier in this activity, you were asked to think about the implications of increasing insolation on the greenhouse effect. As was mentioned in the introductory information, the amount of energy being radiated by the Sun has not always been the same as it is now. Looking at how the number of sunspots has varied over time can show the changing activity of the Sun. In general, a large number of sunspots reflects greater solar activity, the more active the sun is, the more energy it radiates.

Some skeptics of human-induced climate change blame global warming on natural variations in the sun's output due to sunspots and/or solar wind. They say it's no coincidence that an increase in sunspot activity and an increase of global temperatures on Earth are happening concurrently, but view control of carbon emissions as foolishness with negative consequences for our economy and tried-and-true energy infrastructure.

The only way to really find out if phenomena like sunspots and solar wind are playing a larger role in climate change than most scientists now believe would be to significantly reduce our carbon emissions. Only in the absence of that potential driver will researchers be able to tell for sure how much impact solar activity has on the Earth's climate.

Graphs 2-3 show three pieces of information:

- The number of sunspots observed on the surface of the Sun from the year 1600-2010,
- The concentration of CO_2 in the atmosphere since 1960 in ppm and
- The change in average global temperature from 1860-2010

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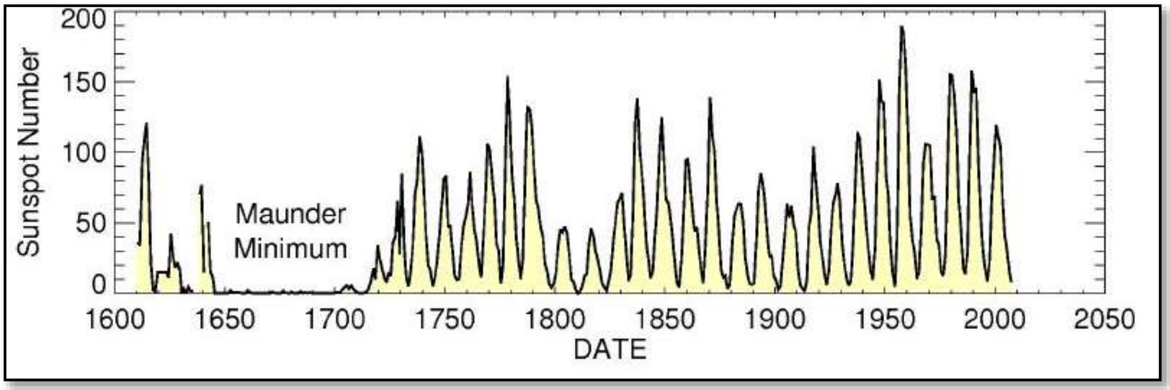
Graph 2: Yearly Averaged Sunspot Numbers 1610-2007



16. The peaks on **Graph 1** represent times when there were sunspot maximums. According to the graph, what two years had the greatest number of sunspots?

17. Was the amount of energy being given off by the Sun during these two times greater than normal or less than normal? Explain.
18. Was the average global temperature higher than normal, lower than normal or about normal for both those times? Explain.

19. Estimate the average number of years that occur between one sunspot minimum and the next one. This time is known as the ***solar cycle.***

20. During what 70-year time period was sunspot activity very low?

This time period has been called the ***Maunder Minimum*** because of the low number of sunspots. On Earth, it was a time of unusually cold weather. Glaciers across the Earth, especially in the Northern Hemisphere, advanced. This time of advancing glaciers has been called the ***"Little Ice Age."***

21. Explain how the Maunder Minimum and the Little Ice Age may be related events.

22. Why can't the first graph alone not be used to draw a definite conclusion about the effects of sunspots on climate change? What other data is needed and why?

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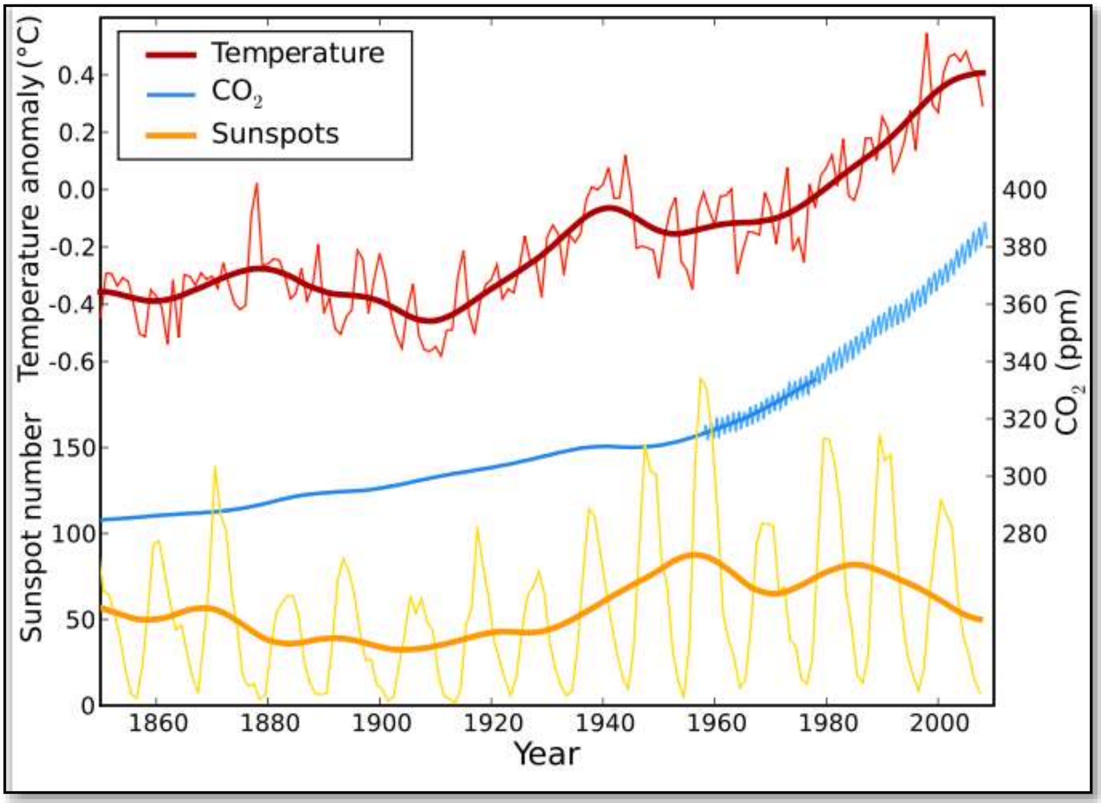
Graph 3: Temperature, CO_2 and Sunspots



23. What additional piece of data is available on **Graph 2**? What time period does this information cover?

24. Why does the CO_2 data still not enough to draw a conclusion?

25. How many sunspot maximums are shown from 1960 -2010? What years did these occur?

26. What temperature anomalies occurred at these times? Explain.

27. What did the CO_2 record indicate for the period being discussed?

28. Discuss how a large number of sunspots in years from 1960-2010 might affect scientists doing research to detect global warming.

29. Can a definite conclusion be drawn with the information show on **Graph 2** about the effect of sunspots on climate change? Explain,