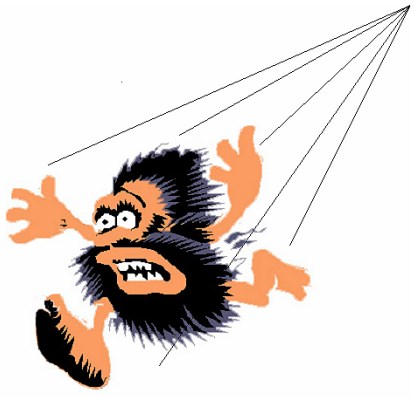
A Cosmic Conundrum

Internet Investigation



Global climate change is caused by

a. Fluctuations in solar activity
b. Variations in Earth's orbit
c. Human burning of fossil fuels
d. Aliens from outer space
e. All of the above

The answer could very well be *e*, all of the above. But…aliens from outer space? That might be true if the aliens in question are *cosmic rays*. More on this possibility shortly.

Many theories have been advanced to explain the warming and cooling cycles recorded in Earth's geologic history. The prevailing explanation for these changes goes like this:

- Normal variations in Earth's orbital motions affect solar energy levels reaching the atmosphere and surface, and therefore control the timing of ice ages. The effect of changes in radiant energy is most pronounced at middle-upper latitudes where glaciers grow and retreat.

- Variations in solar output, for example, those associated with sunspot activity, also appear to influence global temperatures.

- Variations such as these are called external factors, because they originate outside Earth's climate system. However, differences in solar energy alone are not sufficient to cause warming and cooling to the degree revealed by the geologic record. Other, internal, factors appear to be at work as well.

- Internal factors such as water vapor and carbon dioxide buildup in the atmosphere are at least partly responsible for global warming and cooling. Feedback mechanisms in the climate system play important roles. One major example: At times of peak global temperatures, increased water vapor levels in the atmosphere result in greater snowfall at higher latitudes. The accumulating snowfall increases Earth's average albedo (percent of energy reflected), causing less solar energy to be absorbed by the climate system and resulting in a decrease in global temperatures.

- Carbon dioxide and other greenhouse gases are integral to the processes that determine climate and global temperatures. The one-third rise in atmospheric CO_2 concentration since the beginning of the Industrial Revolution is due mainly to man's use of fossil fuels and is considered by many scientists to be a major reason for worldwide temperature increases over the same time frame.

- Still other, natural, factors are known to affect global temperatures. Large volcanic eruptions can spew aerosols (and ash) into the stratosphere, altering Earth's albedo. For example, the 1991 eruption of Mt. Pinatubo, in the Philippines, appears to have depressed worldwide temperatures by as much as 1°C (1.8°F) for a year or more after the event. Meteorite impacts can have similar effects on global climate by ejecting dust and other fine particles into the stratosphere. Huge asteroid impacts in the distant past are believed to have caused extreme climate changes leading to mass extinctions of living organisms.

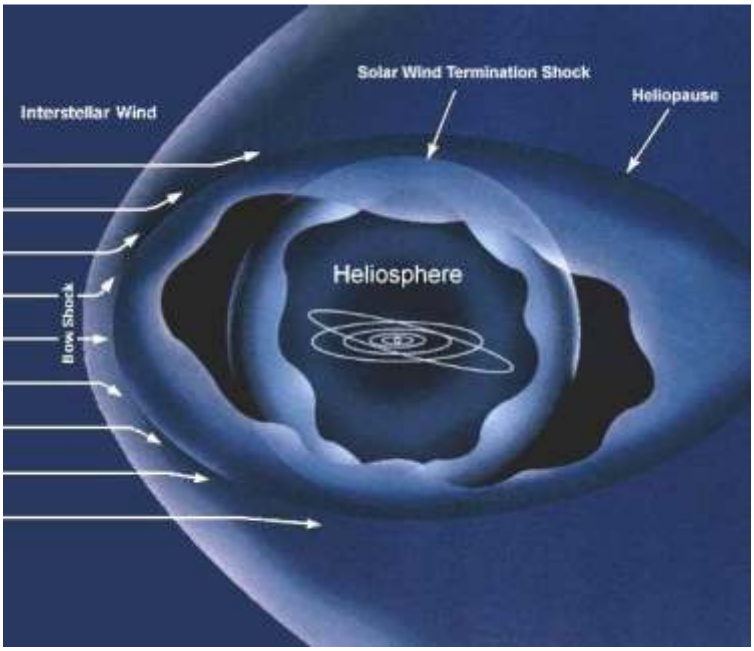
The unusually warm period since 1980, during which the average global temperature has risen almost half a degree Celsius (about one degree Fahrenheit), has intensified interest in the factors contributing to climate change. One recent theory attracting attention is that cosmic rays are related to variations in

global temperatures. To understand how this theory works, it is essential to know what cosmic rays are and how they interact with the *solar wind* within the *heliosphere*.

Cosmic rays are energetic, electrically charged particles made up of atomic fragments. Originally thought to come only from outside the solar system, it is now known that cosmic rays arrive not only from intergalactic space but also from our own Sun as ejected matter in solar flares. Because they are charged particles, cosmic rays interact with the solar wind and with any magnetic field they happen to encounter.

Solar wind is the stream of charged particles continuously emitted from the Sun outward through the solar system and beyond.

Heliosphere is the enormous "bubble" containing the solar system and the solar wind out to its very limits of influence in deep space (see diagram).



Because some intergalactic cosmic rays are very energetic, they could be harmful to life. Fortunately for us, most cosmic ray particles never reach the surface of the Earth. This bit of information is a clue to understanding the connection between cosmic rays and climate change. Visit the following websites to discover more about this subject, and answer the questions below:

http://helios.gsfc.nasa.gov/heliosph.html
http://ngdc.noaa.gov/stp/solar/cosmicrays.html
http://www.mountwashington.org/research/cosmo
http://www.bescenta.co.uk/home/search/cit/4007/shields-up-for-future-space-missions.htm
http://www.dsri.dk/~hsv/Noter/solsys99.html
http://solarscience.msfc.nasa.gov/SolarWind.shtml

1. Scientists have postulated that cosmic rays affect Earth's climate. How may cosmic rays be connected to global temperature changes? Be sure to include mention of the Sun, the solar wind, the heliosphere, and Earth's atmosphere in your response.

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2. The following two website articles describe the possible connection between cosmic rays and global temperatures, and also highlight the uncertainty among scientists about this topic.

   http://news.bbc.co.uk/1/hi/in_depth/sci_tech/2000/climate_change/1026375.stm
   http://news.bbc.co.uk/1/hi/sci/tech/3036032.stm

   Based on these news reports, why is the cosmic ray theory uncertain, and how might this issue affect the debate about controlling manmade carbon dioxide emissions?

3. Find one web or journal article that gives a dissenting view of the cosmic ray theory of global warming. Cite the reference and provide a brief summary of the opposing opinion.

It is hardly surprising that disagreement exists over the causes and effects of climate change. Earth's climate system is extremely complex and difficult to model because of the huge number of variables affecting climate. Some are internal to Earth's own workings, like ocean temperatures; while others are external, such as solar variability. With complexity comes uncertainty – and a great many unanswered questions. Scientists continue to attack these questions on many fronts.

One important area of study is the Sun-Earth connection. In the next few years, NASA scientists will expand our knowledge of solar ejections and their effects on Earth as they carry out a mission called STEREO (Solar Terrestrial Relations Observatory). To learn more, visit:

http://stereo.gsfc.nasa.gov/
http://stp.gsfc.nasa.gov/missions/stereo/stereo.htm
http://stereo.jhuapl.edu/

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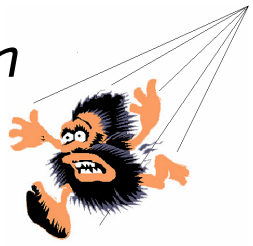

Teachers' Notes

Objectives: Students will learn about the solar wind, the heliosphere, and cosmic rays. They will investigate the possible influence of cosmic rays on global climate using Internet-based resources.

Grade Level: High

NSES: A5, A6, B7, B10, D7, D10, E7, F10, F14, F15, F16, G5, G6, G7

NHSCF: 1a, 2c, 4a, 4b, 5b, 5f, 6a, 6b

Key Concepts

Scientists generally agree that the Earth warms and cools in response to a combination of *external* factors such as solar flux and *internal* factors such as CO_2 concentrations. Recent evidence indicates that cosmic rays, an external factor, may play a significant role in global temperature changes. However, not all scientists embrace this theory.

The Sun's magnetic field and the solar wind act as a shield for the solar system against intergalactic cosmic rays, but some cosmic rays get through. Most cosmic rays that reach Earth are scattered and absorbed by the atmosphere. Supporters of a connection between climate change and cosmic rays argue that variations in solar output modulate the intensity of cosmic rays arriving at Earth. During times of heightened solar emissions, the solar wind intercepts more of the incoming cosmic ray particles and prevents them from reaching Earth. At times of reduced solar activity, the reverse is true. So, how might cosmic rays affect climate?

An increase in cosmic rays during periods of reduced solar output has been associated with increases in global cloud cover. Increasing cloudiness could have a cooling effect by reducing Earth's albedo. Some recent data, in fact, correlate higher cosmic ray measurements with lower global temperatures.

But the opposite effect on temperatures could also be argued. Some scientists suggest that cosmic rays cause low-altitude cloud formation, which would promote warming via the greenhouse effect. Suffice it to say that the role of cosmic rays in cloud formation is not fully understood, and the net effect on global temperatures in uncertain.

Proponents of the cosmic ray connection claim that cosmic rays may be as important to global warming as are carbon dioxide and the other greenhouse gases. The relative importance of cosmic rays to global warming has therefore become a focal point in the debate over placing limits on manmade CO_2 emissions. If, as some people believe, cosmic rays are a big player in controlling global temperatures, mandated CO_2 reductions may not have the total desired effect.