


Global warming – the science

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(first in series)

This series of articles will focus on global warming, the science behind it and the impact global warming may have on Midwestern agriculture. Climate change refers to any change in climate over time, whether due to natural variability or as a result of human activity.

The warming and cooling cycles

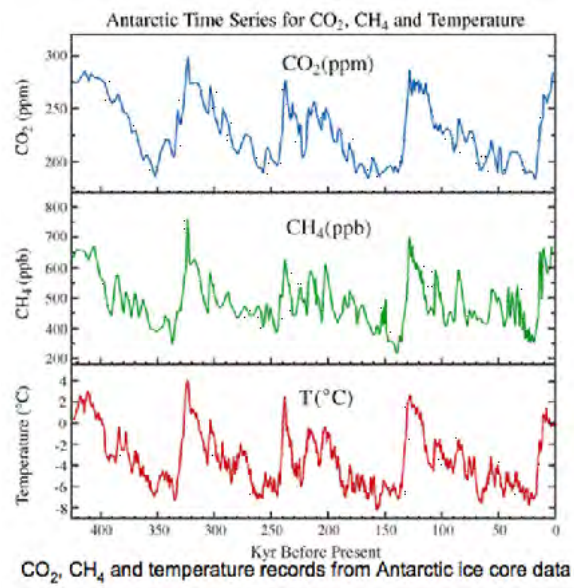
The earth has been going through periods of global warming and cooling for hundreds of thousands of years. With the use of "ice cores" of ancient ice layers, scientists have determined ancient temperature fluctuations in our atmosphere. The bottom line in Figure 1 shows temperature fluctuations over the most recent 430,000 years. Temperature during this period shows a rather regular cycle lasting about 100,000 years. The variation in temperature during a cycle is about 10 to 12 degree centigrade. Although the temperature line appears to move up and down abruptly, in reality the rate of change is very gradual over thousands of years due to the enormous time span covered by the chart.

During the last 15,000 years, we have been in a period of global warming with temperature rising. If we follow the traditional cycle, we would expect temperature to start a gradual decline over the next 70,000 to 80,000 years.

Two of the major greenhouse gases are carbon dioxide (CO_2) and methane (CH_4). Scientists have been able to track the historic concentration of these two greenhouse gases in our atmosphere. As shown in Figure 1, they track closely with the changes in temperature. The central question facing the science community is what will happen to temperature due to the recent and expected future increase is greenhouse gases.

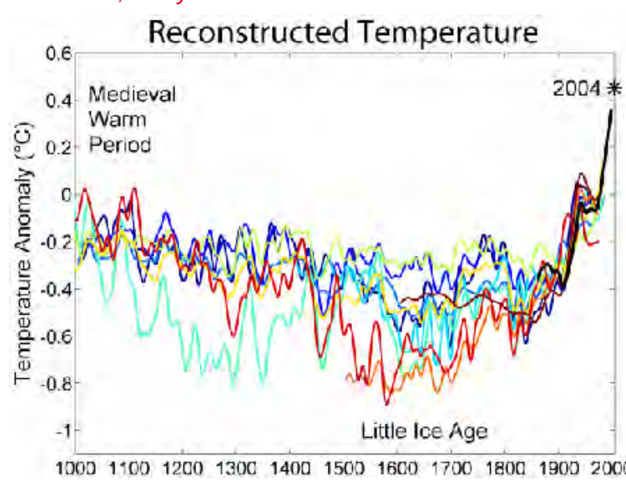
Temperature variations over the last 1,000 years are shown in Figure 2. This figure shows a comparison of ten different published reconstructions of average temperature changes. A pattern emerges of very gradual cooling over the first 900 years followed by a period of rapid warming during the last 100 years.

Figure 1. Antarctic time series for CO_2, CH_4 and temperature variations over the last 430,000 years.



Source: Vimeux, F., K.M. Cuffey, and Jouzel, J., 2002, "New insights in Southern Hemisphere temperature changes from Vostok ice cores using deuterium excess correction", Earth and Planetary Science Letters, 203, 829-843.

Figure 2. Reconstructed temperature variations over the last 1,000 years.



Source: Global Warming Art, http://www.globalwarmingart.com/wiki/Image:1000_Year_Temperature_Comparison_png

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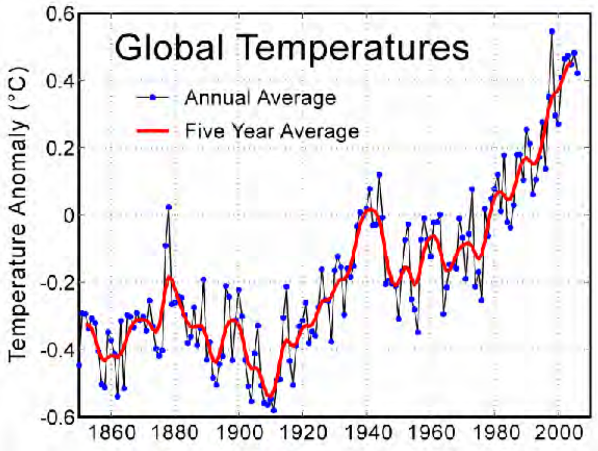
Figure 3. Temperature variations over the last 150 years.



Source: Source: Global Warming Art, http://www.globalwarmingart.com/wiki/Image:Instrumental_Temperature_Record_png
Compiled by the Climatic Research Unit of the University of East Anglia and the Hadley Centre of the UK Meteorological Office.

Temperatures over just the last 150 years since 1850 are shown in Figure 3. The annual average temperature varied greatly from year to year. However, by using a five year moving average, a trend can be deciphered. The trend was relatively flat from 1850 to 1900. Then it increased significantly during the 20th Century (although it dipped briefly from 1900 to 1910 and 1940 to 1950).

Global climate models

The scientific community creates complex climate computer models in an attempt to predict future global temperature changes. The accuracy of a model can be verified by its ability to predict past global temperature changes. Figure 4 shows the accuracy of a model based on five known climate change factors. As can be seen, temperature estimates made by the model tracked quite closely with the actual temperature levels during the period of 1900 to 1990.

The five climate change factors contributing to departures from long-term global average temperatures are greenhouse gas concentration, solar intensity, ozone levels, volcanic activity and sulfate levels. Three of these factors are anthropogenic and two of them are naturally occurring.

Anthropogenic effects are those that are derived from human activities, as opposed to those occurring in natural environments without human influences.

The natural factors are:

1) Solar

The absorption of solar energy heats up our planet's surface and atmosphere and makes life on Earth possible. Sunspots correlate to the changes in intensity of solar radiation reaching the earth. Sunspot activity goes through variations and cycles, so it has the ability to warm and cool the earth compared to the long-term average. As shown in Figure 4, solar activity has contributed to warming (tracks above the dashed line) over the last century. Future sunspot activity will influence the amount of solar radiation reaching the earth and will impact global warming.

2) Volcanic

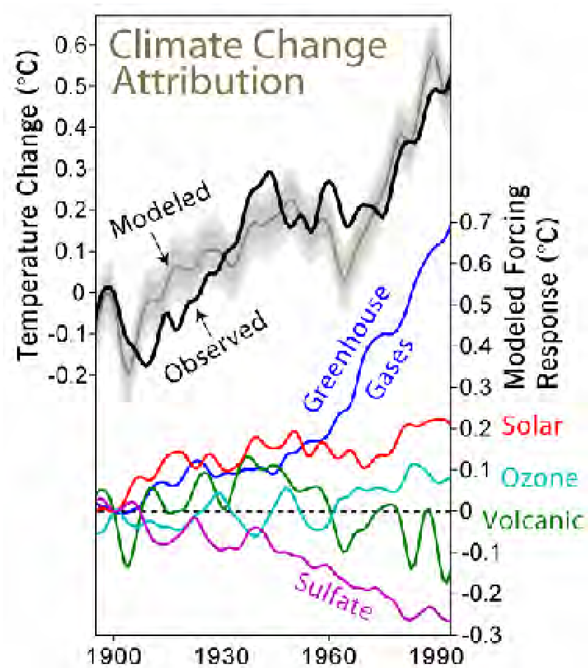
Volcanoes temporarily cool the earth. A decrease in volcanic activity during the first half of the century led to temperature increases, but more volcanoes during the last half contributed to cooling.

The anthropogenic factors are:

1) Greenhouse gases

Solar energy heats up the earth's surface. But

Figure 4. Natural and anthropogenic contributions to global warming.



Source: Global Warming Art. http://www.globalwarmingart.com/wiki/Image:Climate_Change_Attribution_png.
Natural and anthropogenic contributions to global temperature change (Meehl et al., 2004). Observed values from Jones and Moberg 2001. Grey bands indicate 68% and 95% range derived from multiple simulations.

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the energy does not stay bound up in the Earth's environment forever. Instead, as the earth warms, it emits thermal radiation (heat). This thermal radiation, which is largely in the form of long-wave infrared rays, eventually finds its way out into space, leaving the Earth and allowing it to cool. However, instead of passing into space, some of the infrared rays (heat) are absorbed by greenhouse gases and held in the atmosphere. Higher concentrations of greenhouse gases hold more heat in the atmosphere.

The major anthropogenic greenhouse gases are carbon dioxide, methane, nitrous oxide and chlorofluorocarbons. As shown in Figure 4, greenhouse gases in the atmosphere have increased substantially, especially since 1960. More information on greenhouse gases will be presented in the next article.

2) *Ozone*

Ozone is a gaseous atmospheric constituent. In the troposphere (layer of the atmosphere closest to earth), ozone is created primarily by human activity. In the stratosphere (atmospheric layer above the troposphere), ozone filters potentially damaging ultraviolet rays from reaching the Earth's surface. Ozone acts as a modest greenhouse gas, As shown in Figure 4, the contribution due to atmospheric ozone has changed modestly over the last century, with warming due to increase in tropospheric ozone partially offset by cooling due to loss of stratospheric ozone.

3) *Sulfate*

Sulfates occur as microscopic particles (aerosols). They increase the acidity of the atmosphere and form acid rain. They are known to reduce the effects of global warming. Sulfate particles have the capacity to scatter light rays, effectively increasing the earth's albedo (surface reflectivity). Also, the particles act as "cloud condensation nuclei." Essentially, these are particles around which cloud and rain droplets form. The abundance of these nuclei means that more and smaller water droplets form which diffuses light rays. As shown in Figure 4, the global increase of sulfate particles in the atmosphere due to industrial emissions (primarily in developing countries) is contributing to a cooling of the global atmosphere, which offsets part of the warming due to greenhouse gases.

The model shown in Figure 5 also estimates global temperature. When both natural and anthropogenic factors are included in the model, the prediction is closely correlated with the actual observations. However, when just the natural factors (solar and volcanic activity) are included in the model, a discrepancy emerges. Although the natural factors are a good predictor of actual warming in the early part of the century, in about 1960 they start to diverge. By themselves the natural factors do not account for the rise in global temperatures since 1960. Only when they are combined with the anthropogenic factors of greenhouse gases and sulfate does the model predict relatively accurately the actual temperature levels. This leads us to believe that anthropogenic factors have a significant role in the recent increase in global temperature.

The next two articles in this series focus on the role of greenhouse gases in global warming and the potential impact of global warming on Midwestern agriculture.

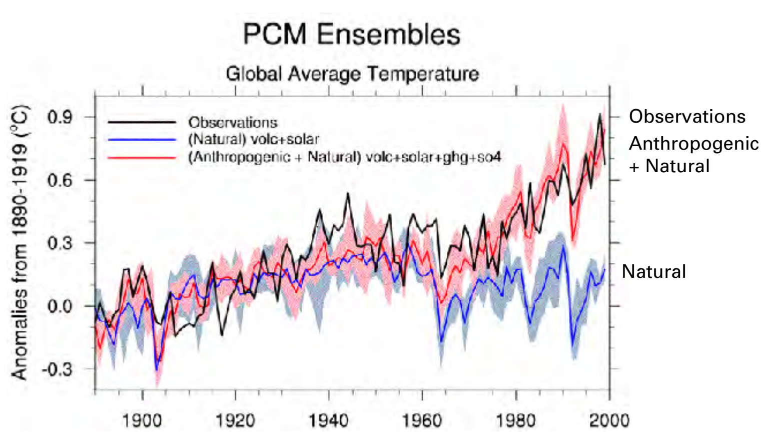
References

Intergovernmental Panel on Climate Change. 22 Jan 2008. <http://www.ipcc.ch/>.

Introduction to Climate Change. United National Environmental Programme. 22 Jan 2008. <http://www.grida.no/climate/vital/intro.htm>.

Global Warming Art. 22 Jan 2008. <http://www.globalwarmingart.com/>.

Figure 5. Global average temperatures (observed temperature versus predicted temperature)



Source: Jerry Meehl, National Center for Atmospheric Research