Global Climate Change

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C O N N E X I O N S

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Baker Institute for Public Policy[1]

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[1] This content is available online at <http://cnx.org/content/m23464/1.2/>.
[2] http://www.bakerinstitute.org

Chapter 2

Introduction to Frequently Asked Question About Climate Change and Why You Should Ask Them[1]

Global Climate Change, at times referred to as global warming, is a phenomenon involving interrelated changes among the various parts of the earth system: atmosphere, biosphere, hydrosphere and lithosphere. As such, an understanding of the subject requires integrating knowledge from very nearly all of the traditional sciences as well as some newer ones such as atmospheric science, biogeochemistry and climate modeling. No one can expect to have a completely comprehensive scientific grasp of the entire subject, but I believe that almost everyone can develop an informed position on it. To this end, I have assembled a set of frequently asked questions and answers with the hope that it may aid those who are interested in obtaining the necessary knowledge.

The phrase "global climate change" itself is loaded with meaning. Global refers not only to a region or even a continent, but also to the whole Earth system. Climate on the other hand encompasses the long time average of a specific region's weather. It references an average value of temperature, rainfall, soil moisture, etc. for a place, such as Houston, Texas or southwest Iowa. Global climate must therefore describe a single combined average of local and regional climate values. In order to specify a global temperature average, one must gather and analyze temperature data from stations representing every climate region on Earth. Change in the global climate does not mean simply a deviation from the "average" or seasonal changes in weather. It does not even mean localized deviations in climate, but rather an actual shift in the averages of climate parameters over the entire globe. An understanding of global climate change can be viewed as four cumulative steps:

1. Detecting, over time, a definite trend in the direction of change in the global climate: Is it really happening?"
2. Attributing climate change to anthropogenic (human induced) or natural causes: Who and what are the real causes of climate change?
3. Modeling climate to determine the degree and effect of future climate change: What can we expect?
4. Responding to climate change predictions: What if anything can be done about it?

[1] This content is available online at <http://cnx.org/content/m21054/1.2/>.

Chapter 3

Q1: Is Global Climate Change Really Happening?[1]

3.1 Detecting, over time, a definite trend in the direction of change in the global climate: Is it really happening?

3.1.1 Short answer

The Synthesis Report based on the fourth assessment of the Intergovernmental Panel on Climate Change (2007) reports, "Warming of the climate system is unequivocal."

3.1.2 Detailed answer

This conclusion is now evident from observations of atmospheric and oceanic temperature. Global surface temperature, includes both surface air temperature measurements at terrestrial weather stations and sea surface temperature measurements from ships and satellites. Temperatures from each station are averaged over day and night as well as throughout the seasons of the year. The results show a global average surface temperature increase of 1.4 °F (0.78 °C) since 1905, with about 1.1 °F (0.61 °C) of the increase occurring since the mid 1970's. Nine of the ten warmest years ever recorded occurred during the past decade. The average increase in sea surface temperatures has been about half that of air temperatures.

Other changes in climate have been observed such as changing precipitation patterns, drought and floods, storm intensity, polar and glacial ice melt and seasonal disruptions of terrestrial ecosystems. Predicting these regional changes with climate models is difficult and incomplete, so questions remain as to how correlated these changes are with respect to increasing greenhouse gases in the atmosphere.

Rain and snow patterns have shifted during the past century. Precipitation has increased in eastern parts of North and South America, northern Europe and central Asia but has declined in the Mediterranean, parts of Africa and southern Asia.

There is good evidence for an increased intensity of tropical cyclonic storms in the north Atlantic with less convincing evidence elsewhere. There is no clear indication of an increased frequency of tropical cyclones.

A decrease in the extent of polar ice and snow is evident. Late summer Arctic sea ice is shrinking at the rate of about 8% per year and may result in an ice clear summer Arctic Ocean in 20 to 30 years.

Melting of Greenland's ice sheet is speeding up. NASA satellite data show the melting rate has accelerated since 2004. Estimated monthly changes in the mass of Greenland's ice sheet suggest it is melting at a rate of about 239 cubic kilometers (57.3 cubic miles) per year. There is no clear evidence that this rate will be maintained or that the ice sheet will stabilize. Since Greenland ice contains about as much water as the Gulf

[1] This content is available online at <http://cnx.org/content/m21055/1.3/>.

of Mexico or something of the order of 600,000 cubic miles, there appears to be little danger of a complete meltdown in the next century. Other ice systems are also melting at an accelerating rate. This loss of glacier ice is evident for most of the world's glaciers. Perhaps the most dramatic glacier withdrawal has been in the Alps, where it has occurred in full view of residents and tourists. An 1859 etching of the Rhone glacier in the Canton of Valais, Switzerland shows the ice filling the valley. In 2001 the glacier was nearly out of sight, 2.5 km (1.6 miles) distant and 450 meters (1500 feet) higher.

Sea level has been rising about 1 to 2 centimeters per decade due to the water gained from the melting of ice caps, ice fields, and mountain glaciers in addition to the thermal expansion of ocean water. Recent studies indicate that about 12% of this rise comes from ice shedding from the Greenland and Antarctica ice sheets. The remaining 88% is due to the expansion of warming sea water and melting from mountain glaciers and other ice caps. This rise is consistent with the general warming of the Earth system.

Because climate is quite a chaotic phenomenon involving a multitude of effects, not every year will be warmer than the last or will other weather events such as hurricane intensity or ice melting increase annually in a smooth fashion. However the modeled trends are certainly consistent with what might be expected from the increase in the observed atmospheric greenhouse warming. For example, while some regions of Antarctica, particularly the peninsula that stretches toward South America, have warmed in recent years, weather stations in other regions of Antarctica, including the one at the South Pole, have recorded a cooling trend. Recent studies however now show that there is warming across the whole continent–stronger in winter and spring but it is there in all seasons. "These data indicate the eastern region of the continent, which is larger and colder than the western portion, is warming at 0.1C per decade, while the west is warming at 0.17C per decade – faster even than the global average.

Chapter 4

Q2: What are the Causes of Global Climate Change?[1]

4.1 Attributing climate change to anthropogenic or natural causes: Who and what are the real causes of climate change?

4.1.1 Short answer

A general consensus exists that the climate is changing and the globe is warming. However, there remain questions with some people as to the cause. Unfortunately these questions have sometimes descended into a debate with one side claiming natural causation and the other side asserting manmade or anthropogenic cause. As is the case in most complicated issues, the answer lies somewhere in the middle. When asked, "Is climate change due to natural cycles or greenhouse gases?" the answer is "Yes." Both natural and human factors are driving climate change.

4.1.2 Detailed answer

On a geological time scale, the climate has changed many times in the past, even before the presence of humans. These changes were obviously naturally caused because man had not yet evolved. A well-known example of climate is the occurrence of ice ages. The earliest well-documented ice age occurred from 850 million to 630 million years ago. The best-characterized ice ages are the most recent ones. These have been detected for at least the past 600,000 years. A geologic history of these ice events is preserved in the ice sheet covering Antarctica and Greenland. It has been uncovered over the past several years by scientists who have cored deeply into the ice and have deciphered the temperature and atmospheric composition records frozen in the ice. The temperature at which the ice originally formed can be obtained from an interpretation of the measured ratio of the stable isotopes of oxygen in the molecules of water forming the ice. The atmospheric gas composition is taken from air bubbles trapped in the ice at the time of formation.

The 100,000 year major cycle of the ice ages and some variations within the cycles agree very well with predicted periodic relationships between the Earth's and the sun's orbits (generally referred to as the Milankovitch cycles). These are very long term changes. They do not significantly affect the climate change that is currently happening with much greater rapidity.

The Earth receives energy from the sun and in turn radiates energy back into space. When these two energies are equal, a stable temperature of the Earth is achieved. This temperature can be calculated from basic physics and is equal to about 0 °F (-18 °C). This "thermal equilibrium temperature" is obviously not that of the surface of the Earth which has an average value of about 59 °F (15 °). The difference between

[1] This content is available online at <http://cnx.org/content/m21057/1.3/>.

these temperatures is due primarily to the natural greenhouse gas concentrations in the atmosphere. The influence of the "natural greenhouse gases", mainly water and some carbon dioxide, moderates the Earth's climate and makes life possible. If the Earth had no naturally occurring atmospheric greenhouse gases, the temperature of the surface of the Earth would equal the thermal equilibrium temperature.

The industrial revolution began to make major changes in manufacturing and transportation around the world. Beginning in Britain, industrialization spread through Europe and North America, eventually affecting the whole world. The development of steam power, fuelled by coal, and later transportation, beginning with the discovery of large deposits of oil, had enormous influence on the economic and social structure of the world. As the world accelerated in the production and transportation of manufactured goods, so the production and consumption of these fossil fuels grew. General prosperity and economic growth continued to increase, and so did the production of carbon dioxide, the combustion byproduct of industrial success. This carbon dioxide and other byproducts of human activities, e.g. deforestation, agricultural gases from rice fields and cows, and industrial nitrous oxide and chlorofluorocarbons added significant concentrations of greenhouse gases to the atmosphere. By 1990, over seven billion tons of carbon (equivalent to 26 tons of carbon dioxide) were being emitted into the atmosphere every year. Similar to the action of the naturally existing greenhouse gases, any additional greenhouse gases would lead to an increase in the surface temperature of the globe.

In addition to new greenhouse gases, other man made changes may be forcing climate change. Increases in near surface ozone from internal combustion engines, aerosols such as carbon black, mineral dust and aviation-induced exhaust are acting to raise the surface temperature. Other aerosols such as those formed from emitted sulfur compounds reflect sunlight and thus act to lower the surface temperature. The reduction of ozone in the stratosphere, production of sulfate, biomass burning and land use changes are acting to change the surface temperature. Transient natural events such as volcanic eruptions and cyclic effects such as small changes in solar energy also can cause both positive and negative temporary changes in the surface temperature.

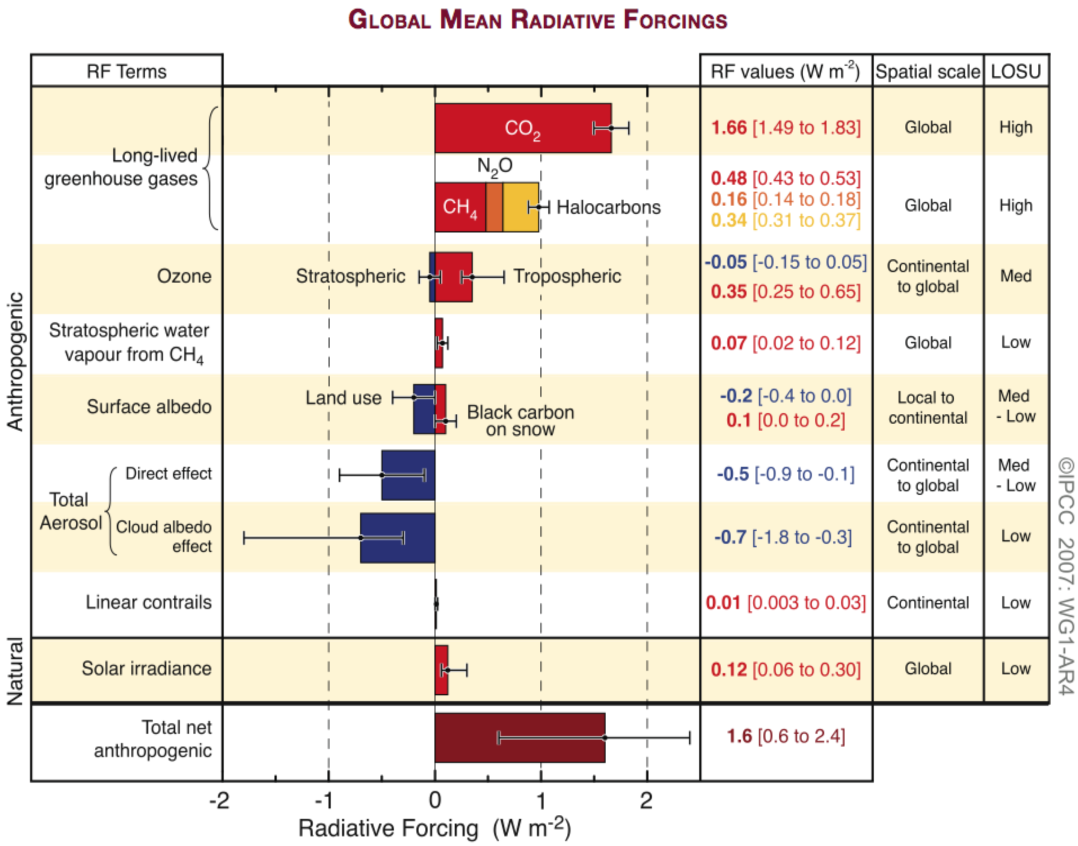

Figure 4.1: Global mean radiative forcing terms divided into anthropogenic and natural causes. Blue bars indicate a negative or cooling effect on the climate and red indicates a positive or heating effect. Greenhouse gases other than carbon dioxide are shown in a different colors which are all heating effects (IPCC, Working group 1, 2007).

Figure 4.1 shows a listing of climate change forcing effects and their 90% confidence levels in 2005 for various agents and mechanisms. These forcings are given in units of Watts/meter squared, a commonly used unit of power measurement. These may be compared to 343 Watts/meter squared, the average amount of energy from the Sun that strikes the Earth's outer atmosphere. They are both natural and anthropogenic and are both positive and negative causing an increase or decrease change in temperature, respectively. Blue bars indicate a negative or cooling effect while red bars indicate a positive or heating effect. The greenhouse gases other than carbon dioxide (methane, nitrous oxide and halocarbons are shown together with different colors for each gas. LOSU represents the level of scientific understanding or confidence level. Volcanic aerosols contribute an additional form of natural forcing but it is not included because of the short lifetime of the effect.

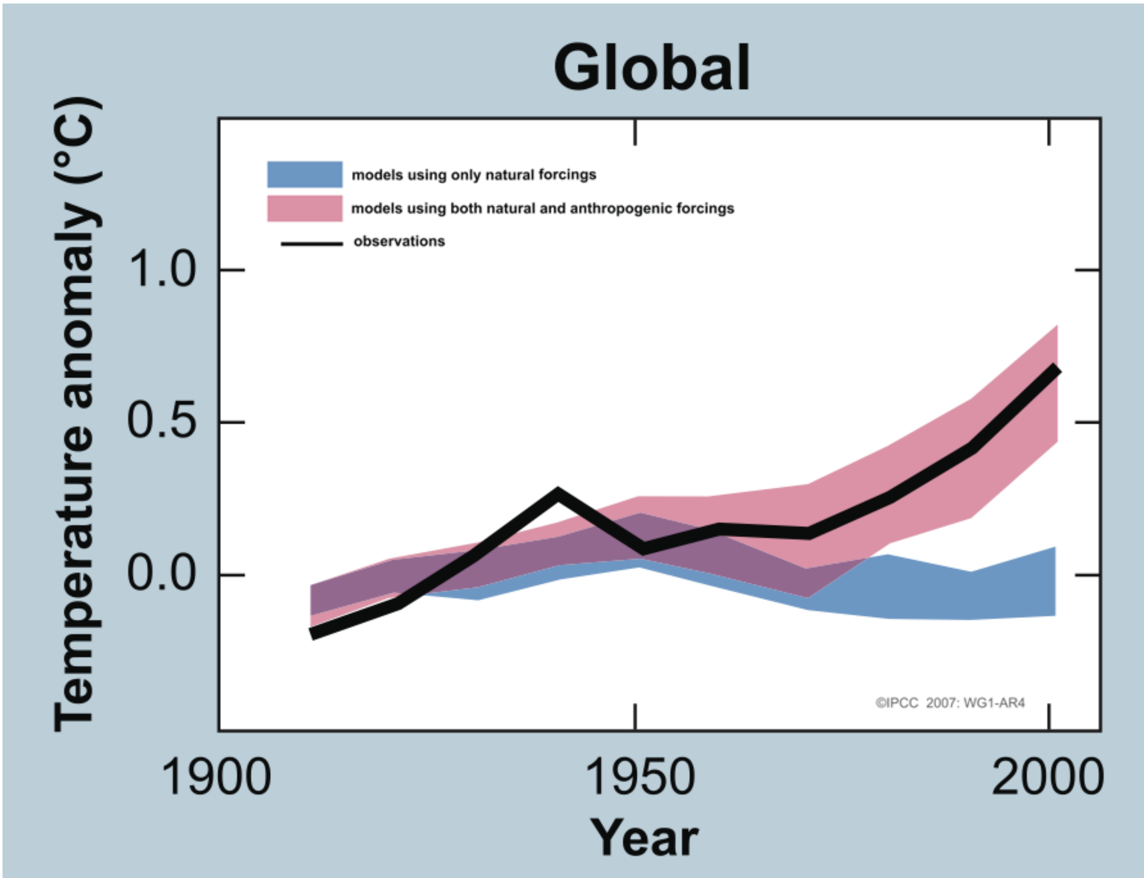

Figure 4.2: Comparison between observed average global temperatures and corresponding modeled temperatures with and without anthropogenic climate forcings (IPCC, Working group 1, 2007).

A comparison of observed global-scale changes anthropogenic effects is presented in Figure 4.2. The decadal averages of observations are shown for the period 1906 to 2005 (black line). All temperatures are plotted relative to zero being defined as the corresponding average for the period from 1901 to 1950. The blue shaded band shows the 5% to 95% range for 19 simulations from 5 climate models using only the natural forcing effects due to solar activity and volcanoes. The red shaded band shows the 5% to 95% confidence range (common limits of confidence in the model calculations) for 58 different simulations from 14 climate models using both natural and anthropogenic forcings. These different simulations and the different models are used by different scientific groups and represent different treatments of the Earth system. It is thus quite encouraging that model calculations are in major agreement with the assumption that global temperature change from 1900 to 2000 is due to both natural and anthropogenic effects, with anthropogenic effects being the major causes in its recent dramatic increase.

Chapter 5

Q3: What can We Expect from Modelling Climate Change[1]

5.1 Modeling climate to determine the degree and effect of future climate change: What can we expect?

5.1.1 Short answer

The future global surface temperature and some other climate variables can be modeled with reasonable confidence for various scenarios for the future energy policy of the globe. These results are only as good as our ability to predict the actual energy consumption patterns of the whole world.

5.1.2 Detailed answer

Predicting the future with any real precision is virtually impossible. Future climate change depends on several human activities, the most important of which are the use of fossil fuels for energy and continued land use change in the form of new urban communities or reductions of forest areas. The current best way to approach a prediction of future climate is to develop a series of plausible scenarios of future human activity and then run simulations using a multi-model approach to obtain average climate outcomes for each. The results will be an array of different climate futures that can provide a basis for choosing how much climate change we wish to tolerate and what mitigation and life style changes will be necessary to achieve that end.

[1] This content is available online at <http://cnx.org/content/m21062/1.3/>.