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GLOBAL CLIMATE CHANGE: A Review and Update on Climate Science

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What is global climate change?

Climate refers to the general weather conditions and seasonal patterns that prevail in a particular region or locale over an extended period of time. Climates change naturally on a geological time scale. These changes are due to alterations in the sun's intensity, the position of the earth in relation to it, and the shape and location of continents. As climates gradually change, plant and animal species evolve to adapt to new conditions.

Climate is affected by small quantities of "greenhouse" gases in the atmosphere that trap some of the earth's heat which would otherwise escape into space. This is called the "**greenhouse effect**" because it is the mechanism by which greenhouses are warmed for plant growth. The greenhouse effect has kept the earth about 60°F warmer than it would otherwise be and makes life possible. **Global warming** refers to the rapid increase in global temperature now occurring because human activities are increasing the atmospheric concentrations of these greenhouse gases. The term "**Global Climate Change**" includes global warming, but we now understand that warming is not the only effect of human activity on climate.

In 1988, when governments first became alarmed about global warming, the World Meteorological Organization and United Nations Environmental Programme established the Intergovernment Panel on Climate Change (IPCC) to provide independent scientific advice to governments on the complex issue of climate change. The IPCC consists of between 2,000 and 2,500 climate scientists, ecologists, and economists named by their governments. Its purpose is to periodically produce a consensus assessment of all the research findings relating to climate change and its effects. IPPC Assessments have been published in 1990, 1995, and 2001. The next is scheduled for 2007. <www.ipcc.ch>

What do scientists know about global climate change, its causes and effects?

Carbon dioxide is the predominant greenhouse gas. Its concentration in the atmosphere began to increase very gradually in the 18th century due to deforestation, and increased more rapidly in the late 19th century and throughout the 20th century due to the burning of fossil fuels and to more rapid deforestation. It is now 378 parts per million, compared with 270 ppm prior to the industrial revolution, and is currently increasing at about 2 ppm/year.

Other greenhouse gases exist in much smaller amounts, but they trap heat more effectively than carbon dioxide and are increasing more rapidly, so their impacts have become significant. Since the 18th century, methane has increased from 0.70 ppm to 1.76 ppm, and nitrous oxide from 0.270 ppm to 0.319 ppm. Methane is released in fossil fuel extraction, rice wetland production, digestion of cattle and other ruminants, and decomposition of organic wastes from urban dump sites and the raising of livestock. Nitrous oxide is produced from organic decomposition, especially from the soil. Large scale agriculture increases this release of nitrous oxide because of the addition of nitrogen-rich fertilizers. Nitrous oxide is also released from industrial processes, and burning fossil fuels and solid wastes. Sulfur hexafluoride (SF_6) and organic fluorides such as carbon tetrafluoride (CF_4) are much more efficient greenhouse gases that are produced in industrial processes. (Table 1)

Table 1: Global Atmospheric Concentration of Greenhouse Gases

Gas	1700	1998	GWP
CO_2	270[a]	365	1
CH_4	0.700	1.745	21
N_2O	0.270	0.314	310
CF_4	0.040	0.080	6,500
SF_6	0[b]	4.2[b]	23,900

[a]Concentrations in parts per million (ppm) unless otherwise specified

[b]Concentration of SF_6 is in parts per trillion (ppt)

[c]Global Warming Potential (GWP) is calculated based upon persistence in the atmosphere and efficiency of trapping heat relative to that of CO_2 over a 100-year period.

Source: *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 -2000*, U.S. Environmental Protection Agency, Office of Atmospheric Programs, EPA 430-R-02-003, April 2002. <www.epa.gov/globalwarming/publications/emissions>

Considering the global warming potential of the greenhouse gases, it is estimated that about 60% of the overall warming effect is from carbon dioxide produced by burning fossil fuels, 18% from carbon dioxide related to deforestation and land use, 14% from methane, and 8% from nitrous oxide. Synthetic industrial gases, virtually non-existent in 1950, now contribute about 1% of the overall warming effect and they are continuing to increase. The US, with about 5% of the world population, produces over 22% of the annual carbon dioxide emissions resulting from human activity.

In addition to greenhouse gases, there are also effects from particulate matter in the atmosphere. While particulate matter can be from natural phenomena, such as volcanos or forest fires, much of it is due to human activities, especially from power plants and Diesel vehicles. Because it can be washed out of the air by precipi-

tation, particulate matter has a shorter lifetime in the atmosphere than greenhouse gases. Because particulate matter is a complex mixture and its composition changes more rapidly than that of greenhouse gases, it is very difficult to determine what effects it will have on climate.

Particulate matter that reflects sunlight has an overall climate cooling effect, while the light absorbing fraction of carbon, called black carbon, causes climate warming. Some scientists have recently estimated that the atmospheric warming effect of black carbon is second only to that of carbon dioxide, higher than any other of the greenhouse gases.

The IPCC's 2001 Assessment reported that the global average surface temperature of the Earth has increased by about 0.7 ^{O}C (1.3 ^{O}F) over the 20th century, which is 20% greater than that estimated by the Second Assessment Report that reported for the period up to 1994. Since records have been kept, the 16 warmest years have occurred since 1983. To date, 1998 has been the warmest. Since 1999, every year has been warmer than the previous year except for 2004, which was virtually identical to 2003, both of which were almost as warm as 1998.

Ocean temperatures, both on the surface and at great depths, are rising. Because water expands as it warms, global sea level has risen about 7 inches during the 20th century and a full inch from 1995 to 2004. Oceans are also getting more acidic because the increase in atmospheric carbon dioxide means more carbon dioxide is dissolved in the ocean.

The 2001 IPCC Assessment listed a number of observable changes caused by global climate change. The number of extreme weather events (droughts on the one hand and intense storms and floods on the other) has increased, largely because warmer air causes more water to evaporate. The earth's ice cover at the poles and at high elevations is shrinking, and the arctic tundra is thawing. The distribution of vegetation and wildlife has begun to shift significantly, as have growing seasons for agriculture. Outbreaks of dengue fever and malaria, previously limited to tropical areas, are occurring at higher latitudes. Increases in encephalitis and other diseases carried by insects in temperate regions have been linked to global warming. Epidemics of insect infestation and diseases of trees in temperate forests have been related to climate change. (Table 2)

Table 2. Observed Changes in the 20th Century Due to Climate Change

- Duration of ice cover for temperate rivers and lakes decreased by 2 weeks
- Arctic sea-ice thickness thinned by 40% since the 1950s
- Arctic sea-ice extent decreased by 10 - 15% since 1950s
- Non-polar glaciers decreased by 10% since 1960
- Snow cover decreased by 10% since 1960
- Polar, sub-polar and mountainous region permafrost thawed, warmed and degraded
- El Niño events more frequent, persistent and intense since 1970
- Growing season lengthened by 1 – 4 days/decade in higher latitudes
- Plant, insect, bird and fish ranges shifted toward the poles and higher in elevation
- Earlier breeding, plant flowering, bird migration, and emergence of insects in temperate regions
- More frequent and more intense coral bleaching events

Source: IPCC (2001)

The 2001 IPCC Assessment convincingly linked human activity to these changes. Natural factors are possible contributors to all these changes as well, but accumulating evidence pointed more strongly toward human factors. This evidence also strengthened the IPCC's confidence in the ability of computerized climate modeling to anticipate future trends.

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QNL promotes government and corporate policies to help restore and protect Earth's biological integrity. It works within and through the Religious Society of Friends for policies that enable human communities to relate in mutually enhancing ways to the ecosystems of which they are a part. This witness seeks to be guided by the Spirit and grounded in reverence for God's creation.

QEB's purpose is to advance Friends' witness on government and corporate policy as it relates to the ecosystems that sustain us. Each issue is an article about timely legislative or corporate policy issues affecting our society's relationship to the earth.

Friends are invited to contact us about writing an article for ***QEB.*** Submissions are subject to editing and should:

- Explain why the issue is a Friends' concern.
- Provide accurate, documented background information that reflects the complexity of the issue and is respectful toward other points of view.
- Relate the issue to legislation or corporate policy.
- List what Friends can do.
- Provide references and sources for additional information.

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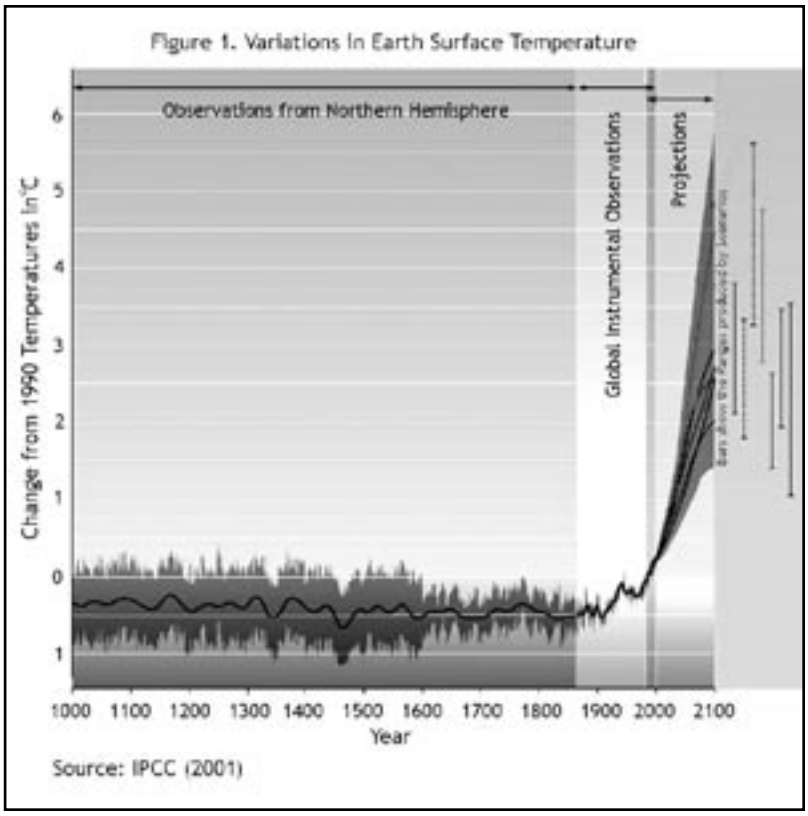
Since the 2001 Assessment, there has been more evidence of ocean warming, increased acidity, and changing circulation patterns; of melting glaciers and of thawing tundra, all of which continue to point toward human activity as the predominant cause of observed climate and ecosystem changes. This new evidence falls well within the range of earlier projections, but the nature and rate of observed changes has led some IPCC participants, including current IPCC chair, Rajendra Pachauri, to suggest that the effects of global warming on climate and ecological systems have been even greater than expected and to speak forcefully in support of stronger efforts to curtail greenhouse emissions.

What do scientists project about future climate change and its effects?

There is no effective way to recapture greenhouse gases on a significant scale once they are released. From a policy perspective, this calls for predicting the future with as much certainty as possible. But from a scientific perspective, making accurate predictions about a system as complex as the climate is not possible for several reasons:

1) The earth's climate system is exceedingly complex. Determining how one factor affects others is difficult and subject to differing standards of evidence and interpretation. Predicting what will happen in the future is even more complex because predictable changes may have unpredictable effects.
2) The climate system has both self-regulating and destabilizing features. As an example of a **negative feedback,** higher carbon dioxide concentrations in the atmosphere are moderated by increasing uptake by the oceans and vegetation. Destabilizing features can amplify small changes, producing **positive feedback**. For example, less snow cover due to warmer temperatures reduces the reflection of sunlight and contributes to warming temperatures. The overall effect of some features are not known or knowable (**indeterminate feedback**). Warmer temperatures may lead to more clouds, which both reflect light and trap heat, but it is not possible to know in advance what kinds of clouds will form, and whether the net effect will hasten or slow the warming trend.
3) Greenhouse gases vary greatly in the amount of time they remain in the atmosphere, from a few hours or days for ozone, to thousands of years for some synthetic chemicals.
4) The most uncertain feature of the future climate system is the nature and scale of future human activity. Will societies manage to restrain their industrial and agricultural emissions, or will emissions continue to increase until industrial and agricultural production is disrupted?

Instead of making specific predictions, climate scientists make a number of projections based on different "scenarios" of self-regulating and amplifying interactions and future human activity. These projections are derived from exceedingly sophisticated super-computer models of the climate system. Thus, the IPCC presents projections in numerical ranges representing the results of models run under the assumptions of different scenarios of the future. (Figure 1)



In a scenario assuming a carbon dioxide equivalent of about 550 ppm (450 ppm of carbon dioxide plus the effects of other greenhouse gases) by 2050, the models project a rise in global temperature of between 2.4 and 10.5°F by 2100. Land surfaces and higher latitudes would experience larger increases.

Sea level is projected to rise between 10 and 30 inches by 2100. Many low-lying regions and small island states would have to be evacuated due to storm surges and saltwater intrusion. Rates of evaporation and precipitation would increase about 1% for every 1°F temperature rise, and their distribution may be increasingly uneven and unpredictable. More frequent and severe heat waves and droughts, and heavier storms and floods would result. Rapid climate change would limit the ability of many plant and animal species to adapt. Insects, rodents, disease organisms, and other species that reproduce rapidly would increase.

In its First Assessment in 1990, the IPCC estimated that to stabilize atmospheric carbon dioxide, global emissions would have to be reduced below 1990 levels by at least 60%. Even after carbon dioxide and other greenhouse gas levels are reduced, the temperature will continue to rise for many years and sea levels will continue to rise for several centuries.

Climate modeling based on the interactions among many variables in the existing system is not able to account for the possibility that the accumulation of particular changes could reconfigure the whole system. Three prominent potential "climate surprise" scenarios have been identified:

1) At present, cold salty water flows into the North Atlantic from the Arctic Ocean and sinks when it meets warmer, less salty water carried from the tropics by the Gulf Stream. This is the "engine" that drives the Gulf Stream. The result is that Western Europe has a much warmer climate than would otherwise be

expected at that latitude. Melting snow and ice in the arctic region is reducing the salt content of the water in the North Atlantic. If this process continues, cold water entering the North Atlantic may no longer sink, so the oceans' circulatory pattern would become very different. There is evidence to suggest that this has happened several times in the past with a rapid change to a much colder climate.

2) The rapid release of huge quantities of methane from arctic tundra as it thaws and from frozen arctic waters would add large quantities of a powerful greenhouse gas to the atmosphere, which would rapidly accelerate global warming and further destabilize climates. Climate instability challenges ecosystem resilience. Weather extremes—heat, cold, drought or flooding—devastate biotic communities as much as they devastate human communities.
3) The rapid disintegration of Antarctic and/or Greenland ice could raise sea levels by many feet within just a few years. Many of the world's cities, industrial areas, agricultural lands, and wetlands habitat would be inundated.

Several years ago, these "surprises" were viewed as possibilities several centuries into the future. Evidence of rapid warming in the arctic regions and new evidence that rapid change has occurred in the past, have led scientists to consider these scenarios more conceivable, though not probable, before the end of this century.

How much can global temperature rise before the capacity of large scale ecosystems to survive is exceeded? Some analysts have suggested that a 2°C rise (3.6°F) above the 1990 average may be as much as many ecosystems can withstand.

Why has there been controversy about what is known and projected?

In 1990, a number of large corporations formed the Global Climate Coalition to oppose the conclusions of the IPCC. The Coalition funded and publicized the work of a few scientists who challenged the IPCC findings, and hired public relations firms to spread doubt about the IPCC's credibility. As a result of these efforts, news reports have tended to present "both sides," and made it seem as though there is much more disagreement among climate scientists than really existed.

In response to the IPCC's 2001 Assessment, many of the original members of the Global Climate Coalition disassociated themselves from those efforts and the Coalition has disbanded. However, there are still organizations such as the Center for Energy and Economic Development, representing wealthy coal and oil interests, that continue to fund public relations efforts to dispute the IPCC findings. Advantages of global warming, such as longer growing temperate seasons, are emphasized.

Those who represent these views now control the US Presidency and are a powerful influence in the US Congress. Soon after the IPCC's 2001 Assessment was released, it was reviewed by a panel of the National Academy of Sciences at the request of President Bush. Although the National Academy's review supported the scientific foundation of the IPCC report, and concluded that "global warming is undoubtedly real," the Bush administration and some members of Congress continue to be critical of the IPCC's findings. One, Senator James Inhofe of Oklahoma, refers to global warming as a "massive hoax."

Who has the "burden of proof" in regard to global climate change?

Opinions are shaped by assumptions that are rarely articulated about who must prove what. In a criminal court, the burden of proof lies with the prosecution, and the protection of a reasonable doubt favors the accused. In a civil court, decisions are based on the balance of evidence.

With regard to greenhouse gas emissions and their effects, who is the prosecution? Who stands accused and receives the protection of a reasonable doubt? There would appear to be three parties: those whose job it is to provide a profitable return to investors, those whose job it is to provide for the general welfare of the electorate, and those who are of the view that the well-being of the earth's biotic community is essential to human well-being, that the long-term well-being of the earth's biotic community is of a higher priority than the short-term well-being of industrial society.

At present, the protection provided by a reasonable doubt lies with those whose job it is to provide investors with a profitable return. The burden of proof lies with those who advocate for the general welfare of the electorate. The balance of evidence seems unpersuasive to the political process as a whole. Those who place a priority on the long-term well-being of the living earth, the "integrity of creation," are for the most part in the audience.

What can Friends do?

What greater sacrilege could there be than to knowingly and wantonly participate in unraveling the fabric of life on Earth as God creates it? Friends are already active on this issue at a number of levels. Friends Committee on National Legislation conducted an extensive campaign to include reduction of U.S. dependence upon oil and greenhouse emissions into the Energy Policy Act of 2005. <http://www.fcnl.org/issues/issue.php?issue_id=24>

Philadelphia Yearly Meeting recently held the "Called Session on Climate Change," which united on a Minute, incorporated into an Epistle. It states, in part:

"Friends at this session unite behind the desire that Philadelphia Yearly Meeting incorporate this concern about the rise of global climate temperatures and its dangerous implications for life on our earth into the body of its work in the world. We feel ready, with divine assistance, to assume the challenges of being prophetic witnesses to protect our earth. We call upon the Yearly Meeting, in all its manifestations, to seek ways to hold our members lovingly accountable to live in God's world in a more environmentally sustainable fashion and to join other like-minded groups and organizations in supporting this concern." <www.PYM.org>

Let us ask ourselves, "How, as a faith community, can we come under the weight of the dysfunctional human-earth relationship in which we are enmeshed, of which climate change is but one of the most pressing manifestations? How can we support one another in our monthly meetings, churches, and worship groups, in taking more of the steps already known to us? How can we, together, seek ways as yet unknown to capture the attention of the larger society about the promise of redemption if we are willing to change?"

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