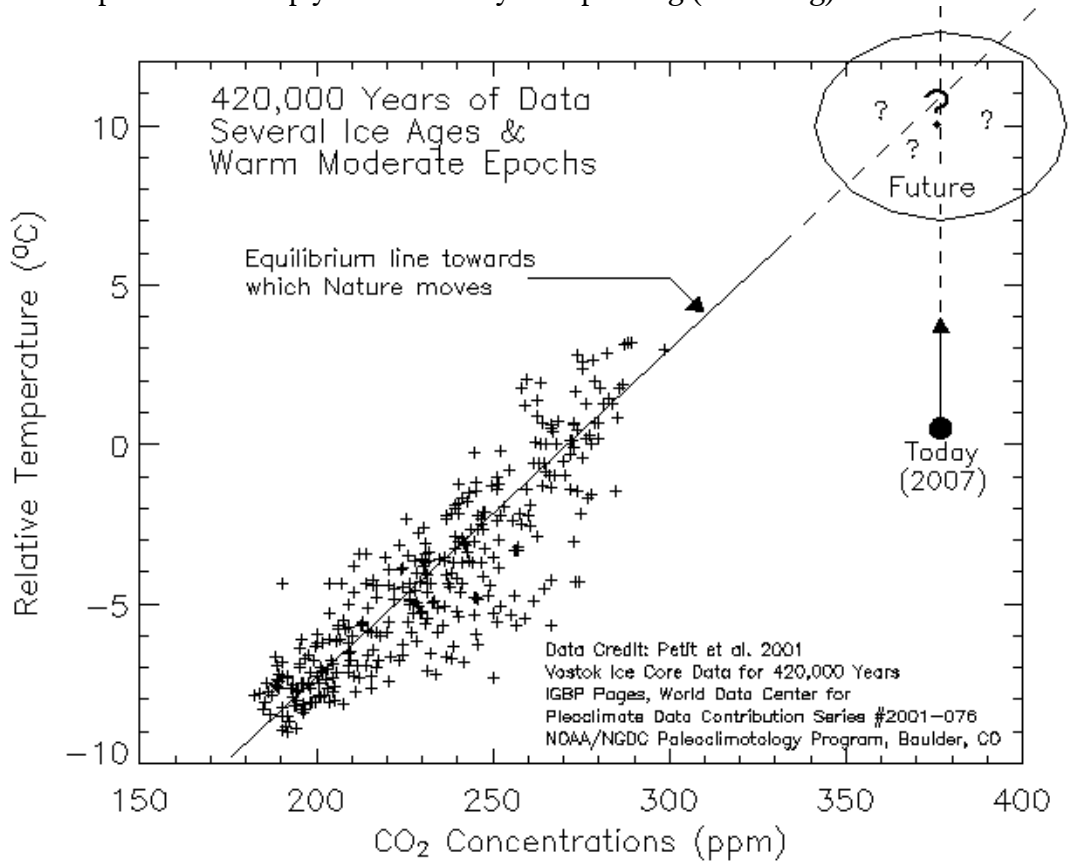


Appendix C: The Global Warming Threat

A scatter diagram, as we saw in the main text of the book, is an extremely useful tool for analyzing statistical data easily. It can be used to infer relationships, to quantify results, and even make predictions. Consider the data from ice samples taken at the Vostok site in Antarctica under the auspices of the National Ocean and Atmospheric Administration's Paleoclimatology Program. Various greenhouse gases along with temperature-sensitive indicators (deuterium) are continually trapped in Antarctica's ice, preserving a historical record of Earth's climate. Scientists use large, hollow-bit drills to retrieve ice samples from the surface down to a depth of 3.3 km (2 miles). The procedure is essentially a much larger version of the forestry methods used to retrieve samples for tree-ring analysis.

In the diagram, I have placed a plus symbol "+" at each value of the average atmospheric temperature and the corresponding CO₂ concentration, spanning the past four hundred thousand years. The historical air temperatures are relative to a late twentieth-century average. These data span several ice ages as well as epochs of moderate temperature, suggesting a natural range of global temperatures and greenhouse gasses. In addition, the data indicate an equilibrium relationship, denoted by the straight line drawn through the "+" data points. That is, pick any amount of CO₂ concentration and the equilibrium temperature will be the corresponding point on that straight line. Note: concentration values less than or greater than those plotted can simply be inferred by extrapolating (extending) the line.



From the scatter, we can readily see there were periods that were warmer than our present day climates, as well as much cooler. This fact has given false hope to some individuals who doubt scientific climate predictions. However, the Earth in the last four hundred thousand years has not seen a sharp increase in CO₂ and other gases, followed subsequently by sustained high levels. In the past, natural CO₂ increases were of two kinds 1) slow drifts over the range of the “+” symbols and 2) short impulses (brief, one-time events such as a mega-volcano eruption). While the latter phenomena had a strong short-term impact, its net long-term driving force was far less than current anthropogenic drivers. I have placed a large solid dot at the location indicated by observations from the Mauna Loa facility in Hawaii. Conservatively, we must infer that humans have nearly doubled the amount of CO₂ above its naturally sustained levels. It should be noted that while carbon dioxide is the man-made greenhouse gas having the greatest impact, other gases make substantial contributions as well and cannot be ignored. The next largest contributor is methane, followed by nitrous oxide. Graphs for those gases also indicate humanity has increased those levels well above the natural ranges.

Given the current levels and not accounting for any future changes, we can find the “natural” or equilibrium temperature towards which the atmosphere will trend by extending the 2007 data point, straight up on the graph to where it crosses the equilibrium line. In other words, the 2007 CO₂ concentration levels implies the mean temperature of the Earth’s atmosphere will eventually rise about 10 °C (18 °F) above its present-day levels. Obviously, it will take some time for Earth to equilibrate to the new mean temperature due to its huge volume and mass. In addition, the most dramatic changes currently taking place are near the polar regions, skewing personal perceptions. For these reasons, most citizens are just now beginning to realize the consequences of the man-made greenhouse effect. Unfortunately, the change already observed, marks only the tip of the iceberg. The full impact will become apparent later in this century. Note: no time scale information can be obtained from our scatter diagram; complex climatology models are required to infer the rate that temperatures will climb. Regardless, it will eventually become common to have summertime high temperatures of 130° to 140° F in places such as southern Arizona, along with temperatures never dipping below 90° F (even at night) for half of the year. Few agricultural crops as well as livestock can survive such extremes. Moreover, other regions will frequently experience strong storms and flooding. The overall losses as well as the year-to-year uncertainties in agricultural productivity will likely lead to riots, wars, and breakdowns in social order since worldwide margins for food production are thin and panic often ensues during real or even perceived shortages.

All of the above consequences assume there are no additional sinks or sources of greenhouse gases. Sinks reduce, while sources increase the atmospheric concentrations. Additional sinks or sources tend to tip the arrow in our graph from its vertical direction, either counterclockwise to the left or clockwise to the right, respectively. Sinks include, for example, an enhancement of absorption by the oceans or enhanced tree growth, increasing the rate that CO₂ is removed from the atmosphere. It is important to recognize that there are no silver bullets. Neither a new sink nor the enhancement of an existing one will materialize to save us. Extra sources include a continued burning of fossil fuels as well as positive feedback mechanisms. For example, vast amounts of natural methane are currently trapped in the permafrost of the northern tundra and will be released as these regions thaw. Considering the range of possibilities, the new sources will strongly out pace any extra sinks, placing the equilibrium temperature and greenhouse gas concentrations well outside

the range plotted. In other words, the current trends suggest the equilibrium values will become greater than 400 ppm for CO₂ and greater than 12° C (22° F) above current temperatures.

Conservatively, I have plotted as a set of question marks with an oval envelope, to show the range of equilibrium values that would result, assuming human activities do not drive concentrations higher. While we cannot be sure exactly what the final equilibrium temperature will become, two things are clear. First, man-made greenhouse gasses are having a significant impact on Earth's environment; the threat is real. Second, we are conducting a highly risky experiment on ourselves, one that will cause enormous amounts of suffering to baby boomers and especially to their children and grandchildren.

The 2007 fourth assessment by the Intergovernmental Panel on Climate Change (IPCC) predicts a slow temperature increase, ranging from 1.5° C to 4.6° C by the year 2100. However, they have probably underestimated the true increase due to three significant factors. 1) Their projections do not reflect a pure objective scientific result, but rather forecasts diluted by politicians. The IPCC has been criticized scientifically for interpreting the evidence too conservatively. 2) The tundra in Northern Canada and Siberia contain an estimated 70 billion tons of natural methane frozen in the form of decayed plants. Once thawed, the released greenhouse gas will be equivalent to burning 56 years worth of fossil fuels at the current 2000-2005 level. This added source is not included in climate models. There is strong evidence that all tundra are rapidly warming with existing vegetation being replaced by substantial shrub growth that traps even more light and heat. 3) Environmental efforts to remove various pollutants and harmful particulates revealed the process of *Global Dimming*. (See the PBS NOVA special on Global Dimming.) The effect has been concealing half of the impact from anthropogenic Global Warming. In other words, had the industrial nations burned the same amount of fuel over the past hundred years, but cleanly as they do now, the contribution to worldwide warming would be nearly twice the amount observed. The full impact of clean burning is just now beginning. If China and other developing nations take actions as well to improve their air quality, then collectively there effectively will be another factor of two increase in man-made gases in this century. If we assess values to each of these three factors, respectively, the driving forces are six times worse ($1.5 \times 2 \times 2 = 6$) than those estimated by the IPCC. The mean temperature in 2100 will be much warmer and rising. Also, there will be enough inertia built into our atmosphere that significant further temperature increases cannot be reversed prior to the start of 23rd century, if then.

Unfortunately, a rational response to this crisis is being seriously impeded by the actions of various religious sects as well as by a few corporate interests. The crisis requires substantial and immediate efforts of remediation. While there are legitimate disagreements about the range of uncertainties, the antagonists overtly inject misinformation into the dialog as well as instill doubts about the veracity of all science, common tactics of people using misology, the hatred of reasoning. ... the delaying actions of anti-rationalists will only worsen the ordeal that must be endured by all. Nature will rebound and numerous species of life will survive, probably including human offspring in some form that may not be recognizable to existing generations.