Climate Change Fundamentals

Increasing Temperatures & Greenhouse Gases

Through the study of ice cores from Antarctica, atmospheric concentrations of the dominant greenhouse gas, carbon dioxide (CO2), can be determined over hundreds of thousands of years. Figure 1 illustrates variations in both atmospheric CO2 concentrations and temperature over the past 400,000 years. A comparison of the two trends indicates a very tight connection between their performances, with fluctuations in one curve almost exactly mirrored in the other. Periods of higher CO2 concentrations are warmer (interglacial); periods with lower concentrations are colder (glacial). In the 1800s – as the Industrial Revolution started – atmospheric CO2 concentrations began an unprecedented upward climb, rising rapidly from 280 ppm (parts per million) in the early 1800s to a current level of 397 ppm, as of 2009. The current concentration is 38 percent higher than it was at the start of the Industrial Revolution.

Figure 1. CO2 and Temperature. Barnola et al, 2003. Data from Oak Ridge National Laboratory.

The Intergovernmental Panel on Climate Change (IPCC)

Noting these trends, and recognizing the potential for dramatic changes in the climate due to continued unchecked accumulation of greenhouse gases in the atmosphere, the World Meteorological Organization (WMO) and the United Nations Environment Program (UNEP) established the Intergovernmental Panel on Climate Change (IPCC) in 1988. The purpose of the IPCC is to review existing and developing peer-reviewed scientific literature to form an objective evaluation about the risk of human-induced climate change.

After years of investigation, and in consultation with thousands of scientists, the IPCC was able to write, in its Fourth Assessment Report in 2007, that "warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level." Their report noted that the dramatic increase in carbon dioxide concentration in the atmosphere over the past 150 years is largely due to anthropogenic (human-caused) effects and concluded that "most of the observed increase in global average temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations. Discernible human influences now extend to other aspects of climate, including ocean warming, continental-average temperatures, temperature extremes and wind patterns."

The IPCC's models predicted a rise of 1 to 5 degrees Celsius (2.0 to 11.5 degrees Fahrenheit) in the global mean surface temperature during the next century, with sea-levels expected to rise by between 7 and 23 inches (excluding possible future rapid changes in dynamical ice flow) 2100. (IPCC 2007). The IPCC continues to play a central role in reviewing and assessing the most recent information on climate change.

Improved Models, Growing Confidence

The Fourth Assessment Report of the IPCC, released in 2007, added weight to the linkage between rising temperatures and continued greenhouse accumulations.

Figure 2. a) Comparison between global mean surface temperate anomalies from observations (black) and model simulations forced with anthropogenic and natural forcings, and b) forced with natural

forcings only. The labeled verticals lines in Figure 2 represent major volcanic events, which generally have a temporary cooling effect on the global climate. Source: IPCC, Fourth Assessment Report, 2007.

For example, recorded global temperature change can be compared with computer models that predict temperature change under different "forcing" – or external influences on the underlying radiative budget of the planet – scenarios. Forcings may include greenhouse gases, aerosols, solar radiation, and other agents). Figure 2 compares observed temperature differences from a historic mean (black lines) with the results of computer models that attempt to predict temperature based on the interactions of other environmental influences (red and blue lines).

Chart B in the figure illustrates that models using only natural influences fail to match the observed record of temperature anomalies since 1900. But the combination of natural and anthropogenic models, as illustrated in Chart A, produces a close match to the observed data. Climate models thus help reveal a clear "thumbprint" of human impacts on climate change.

Based on results such as these, the IPCC's 2007 report stated emphatically that "for the next two decades, a warming of about 0.2oC (0.35 oF) per decade is projected for a range of emission scenarios. Even if the concentration of all greenhouse gases and aerosols had been kept constant at year 2000 levels, a further warming of about 0.1oC (0.2oF) per decade would be expected."

Accumulating Evidence

Other evidence of climate change continues to accumulate. Consistent with predictions of the IPCC since 1990, global average temperatures have indeed been rising, while the rate of atmospheric CO2 has also been increasing (Figure 3). The rate of growth in CO2 concentrations in the first eight years of the 21st century was more than twice the rate observed in the 1960s (Le Quéré et al., 2009).

Figure 3. Global Temperature & CO2 Concentration Since 1880. Data from NOAA's National Climate Data Center (NCDC) & Oak Ridge National Laboratory.

Fourteen of the fifteen warmest years on record since 1850 have occurred in the last fourteen years. In other words, only one year in period 1995 - 2009 (1996) is not one of the fifteen hottest years on record. The warmest year was 1998, followed by 2005, 2003, 2002, 2004, 2009, 2006, 2001, 2007, and 1997, as cited by the Climatic Research Unit, University of East Anglia. The 1990s were the warmest complete decade since 1850, and was, on average, 0.43 degrees Celsius warmer than the period 1961-1990.

Other events illustrate the climatic changes that are likely to become more prevalent under a changing global climate regime:

Glaciers are present on every continent other than Australia and function as reasonably well-distributed indicators of changing global temperatures. Worldwide, glaciers and icefields have been shrinking and receding for at least the last century. The collapse of the 1250 square mile Antarctic Larsen B ice shelf in 2002 was just one of the more spectacular instances of a phenomenon that is likely to become more frequent in a warmer world.

While the Antarctic may actually see some areas of growth in its ice sheet due to increased precipitation under a changing climate regime, the northern Arctic region appears to be even more vulnerable. In a 2004 report by the Arctic Monitoring and Assessment Programme (AMAP), (Impacts of a Warming Arctic: Arctic Climate Impact Assessment), the list of potential changes in the Arctic due to warming includes such phenomena as decreases in sea ice, increasing precipitation and river discharge, thawing of glaciers and permafrost, and changes in plant and animal abundances and distributions.

While it is impossible to establish a direct causal link between greenhouse gas accumulation and individual, relatively short-term climatic events, it is certain that we have been experiencing increasing numbers of climatic events unprecedented in the human experience. It is worth noting that the reduced sea ice cover of the Arctic Ocean, the retreat of mountain glaciers, reduced ice sheets in Greenland and West Antarctica, increased droughts and fires, increased severity of storms and flooding have all occurred with a warming of only 0.75oC (1.3oF). It is also certain that many of the greenhouse gases, including carbon dioxide, nitrogen, and methane, have lengthy residence times in the atmosphere, and that we will continue to be affected for years or even centuries to come by the atmospheric burden we are creating today.

Scientific Consensus Concerning Climate Change

Scientists are agreed about the reality of climate change and the underlying anthropogenic causes, is clear among the scientific community. Scientific investigation now focuses on what the effects of climate change will be.