Chapter 2

Climate and Natural Variability

Climate change is nothing new or unnatural. Climate has been changing since the world began about 4.6 billion years ago. It has changed continually on most time scales we can measure, and it has changed catastrophically, far more radically than what is feared to occur in the next 200 years.

Most climate change occurs on time scales far longer than a human lifetime: centuries or millennia or millions of years. We think the weather we are used to is "natural" because we can't remember it being any other way. Many people wrongly believe that an unchanging climate is "natural," and that climate change is something that Earth is not used to. Actually, climate changes constantly, even on time scales of decades or centuries. In practice, the rule of thumb has been to consider "climate" as the average weather conditions over 30-year time spans. Knowing all we can about natural climate change will help keep potential human-induced climate change in perspective.

During most of its estimated 4.6-billion-year life, Earth did not have the sort of atmosphere that could support life on land. The dominant gas in Earth's early atmosphere was probably carbon dioxide, and it took billions of years for algae in the seas to remove that CO_2 and replace it with enough oxygen to sustain life as we know it on land. Not only would animals and plants have suffocated, but the lack of protection from ultraviolet sunlight would have killed them.

It was not until about 450 to 350 million years ago — "recent history" from Earth's 4.6-billion-year perspective — that plants, insects, and finally fish-like animals came ashore. Until that point the "natural" global atmosphere and climate had been lethal to living things.

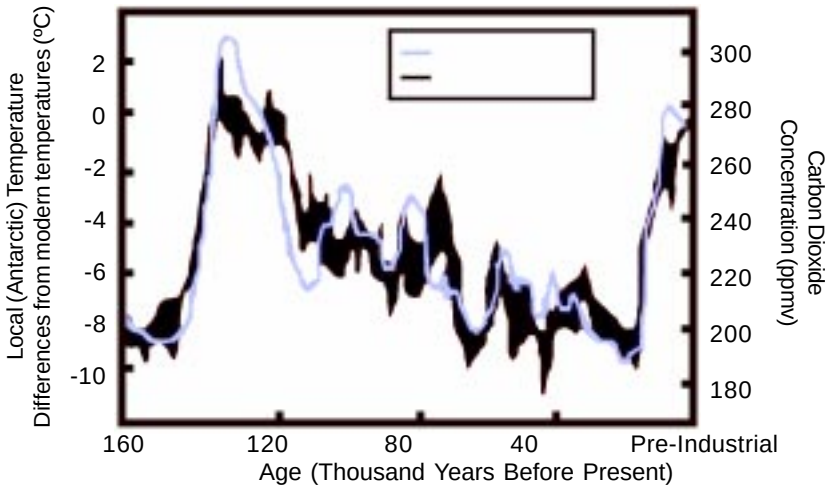
Consider the Carboniferous and Permian periods, a mere 345 to 270 million years ago. It was a world of shallow seas and swampy lands, much warmer and moister than today's climate, covered with profuse growth of giant ferns and primitive trees. It was this climate, much warmer than the worst doomsday predictions for the foreseeable future, that allowed Earth to store carbon from decayed vegetation as coal and oil.

The whole tenure of the human species on Earth is much shorter still — from a million to a few million years, depending on how you define human. Many anthropologists think that climate change helped humans evolve — bringing a change from forest to savanna that forced pre-human primates to come down out of the trees and stand upright.

A look at the "best-guess" graph of Earth's geological-scale climate

trends looks a lot like the temperature chart of a patient with alternating bouts of fever and hypothermia. The wiggles and dips at first seem random and disordered. Climatologists long have been looking for patterns and cycles in climate, and they have found some.

Figure 3. Local Temperature Change and CO_2 Concentrations over the Past 160,000 Years



Source: U.S. Environmental Protection Agency

Patterns are important, because they may mean that aspects of climate change are understandable and even predictable. There are many kinds of climate cycles, some more firmly established than others. Over the very long term, some of the long cooling trend that started before the Cambrian era about 570 million years ago might be explained by the depletion of carbon dioxide in an atmosphere once rich with it. Also over the long term, some climate change can be explained by the tectonic movement and buildup of the continents.

A still more pronounced climate cycle of alternating ice ages and thaws is pretty well explained by the “Milankovitch hypothesis.” These changes in how Earth warms are caused by regular wobbles and tilts in its axis of spin, and by stretches in its orbit.

Still another pattern of climate/weather variation is called the El Niño Southern Oscillation (ENSO). This pattern results from coupled atmosphere-ocean interactions, and recurs at two- to seven-year intervals. The ENSO pattern is driven partly by alternating warmer and cooler temperatures of the sea surface in the eastern and central tropical Pacific Ocean,

which in turn are caused by changes in upwelling currents. It changes rain and temperatures over a large portion of the globe, with drastic consequences to human activities like farming and fishing, which depend on weather and ocean currents. In turn, the changes in weather and atmospheric circulation change the ocean currents.

So the seemingly random squiggles on Earth's temperature chart are not entirely random. Some are the result of natural phenomena. Others are not. Of the variability that remains as yet unexplained, some may be caused by processes we do not yet understand, and some may be truly random or chaotic. The branch of mathematics known as statistics has fairly rigorous tools for attacking the question of what is random and what is not. When these tools are applied to climate data, it appears that some of the variation in global mean temperature from year to year is, indeed, natural, unexplained, unpredictable, and random — what scientists like to call "noise."

This is all relevant to determining whether Earth is getting warmer because of greenhouse gases caused by human activities. Without knowing what the natural variability of global temperature is (random or not), scientists cannot be sure how much extra temperature change is being caused by humans. To take an imaginary example: if natural year-to-year variation in global mean temperature were only a tenth of a degree, and the warming from people's activities were one whole degree, it would be very easy to detect. On the other hand, if the warming were a tenth of a degree and natural variation a whole degree, warming from human activities would be very hard to detect.

Scientists like to use the terms "signal" and "noise," borrowed from information theory, to discuss this problem. If the static on a telephone line is very loud, it is hard to hear a faint voice. On the other hand, if the voice is loud and the static faint (a high signal-to-noise ratio), it is easy to understand the voice.

Right now, the magnitude of the suspected human-induced global warming seems to be not much greater than the magnitude of natural background variation in temperature. This is why the so-called "greenhouse signal" is really difficult to detect with conclusive certainty today. If, as many scientists predict, human-induced warming continues for a few decades more, the warming signal will likely be large enough to detect without much question. Even if a warming trend were found, there would still be the difficult problem of determining whether it was caused by human actions.