

October 22, 2007

Greetings,

Here are some thoughts on how I interpret the subject of global warming. I think global warming appears to be really occurring and greenhouse gas emissions are likely the majority of the cause. There are some natural variations as well, such as from solar cycles and volcanic activity.

CO2 Trends

The reason I would be most concerned is not what has happened so far, but what can very possibly happen if we stay on the present course. Carbon dioxide (CO₂) mainly from fossil fuel burning is being released into the atmosphere faster than natural processes can remove it, thus increasing atmospheric concentrations. The rate of rise in CO₂ concentration has been increasing as well, from about 1.3 parts per million per year several decades ago to about 2.2 ppm/yr in 2005. The natural background is about 280ppm and current CO₂ concentrations are about 380ppm. A linear extrapolation of the 2005 trend would yield a doubling of CO₂ over natural values by around 2080. It is often suggested that short of that, values of just 450ppm would represent a threshold of unacceptable changes in the environment. These values are potentially just a few decades away.

If we wait until things get obviously worse before we take action it could be too late for reasonably quick action to restore our familiar climate. One aspect of the carbon cycle is that even if the global emission rate is held constant, the CO₂ concentration in the atmosphere would continue to rise for quite some time (e.g. one or more centuries) and reach levels several times what it is at present. Alternatively, to hold the CO₂ concentration at current levels, the emission rate would have to be cut by roughly one-half (without considering the effect of the ocean reservoirs filling up). To hold the currently elevated temperature constant the emission rate would need about a two-thirds cut. Even if we magically turned off all emissions at once, it would probably take 100-300 years for CO₂ levels to come down close to the natural background levels. The corresponding "half-life" would be something on the order of 50 years, subject to changes in the various CO₂ sinks. One should also consider the challenge of the developing world's desire to play catchup to the level of per capita emissions of the industrialized world when projecting total global emissions.

Other Factors

It is interesting to note that the estimated solar variations and volcanic activity can account for many past variations in climate such as the Little Ice Age and some temperature fluctuations in the early-mid 20th century. Although the slight cooling in the mid-20th century is consistent with these forcing mechanisms, they cannot explain the more recent warming since about 1970. One has to invoke greenhouse gas effects to explain this recent (and accelerating) trend.

Computer Models

Note that the computer models fit what is really happening in terms of most of the warming being in continental areas in the winter at night (like Colorado on a January evening). Also high latitudes get more warming as witnessed by thunderstorms occurring in Alaska where they haven't before or

Nome having more days over 70 degrees. My guess from the models is about 6 deg F warming from 2000 to 2100. Most models are within about 25% of this value.

Polar Ice

I hear the Larson ice shelf is melting due to warming, yet Antarctica elsewhere may be getting colder, perhaps because of some local interaction with a separate issue such as ozone depletion. Mountain glaciers worldwide are melting apparently faster than the natural value as we come out of the ice age from 10000 years ago. The large Antarctic ice sheets aren't melting much more than the "natural" trend right now, but that could change supposedly on part of the ice sheet if things warm up too much. The bottom of the ice sheets are actually part liquid due to the heat of the earth being conducted from below, so it wouldn't have to warm up too much on the top of the snow pack. So far the melt rate of the Antarctic ice cap (measured by the GRACE satellites, mostly in the West Antarctic Ice Sheet) amounts to roughly a 0.4mm rise in sea level per year and would melt the cap in about 200000 years.

Summer sea ice in the arctic is thinning noticeably and coverage has decreased significantly by about 25% in the past 30 years. Models and recent trends suggest this ice will probably be mostly gone by the end of the century or even sooner. This suggests a major change to the Arctic climate, albedo and ecosystems. The Greenland ice cap shows signs of melting at an increasing rate and is already contributing about 10% (0.25mm) to the annual rate of global sea level rise. This is in contrast to other studies showing some thickening during the 1990s, so it appears there may be some changes underway in the balance of increased snowfall in the interior compared with accelerated melting along the coast. A total Greenland ice cap melt would correspond to around 7 meters of sea level so the current rate would melt the cap in roughly 36000 years. While this appears to be a comfortable margin it is notable compared with the cap having been around for millions of years. It may also continue the current accelerating trend so this linear melting time could shorten dramatically.

Sea Level

The current overall sea level rise rate is about 2-3mm per year or about 1 foot per century. Rates have varied from about 11mm/year at the end of the last ice age to probably well under 1mm/year in recent pre-industrial times. While sea level should be about to peak in this regard, it appears that human caused changes are starting to accelerate the rising trend. The potential for the sea level rise to accelerate further as temperatures warm is supported by geological evidence that the sea level was roughly 12 feet higher during a period of warming about 120000 years that is similar to what is predicted over the next couple of centuries. Thus sea level could continue the rising trend to much higher levels than what we see today. I would anticipate a rise of about 6 inches by 2030 and 2-3 feet by 2100. Sea level could rise much more in the 22nd century.

Then again, humans are a part of nature to take the opposing viewpoint, but these disruptions of climate will likely impact the Earth's biodiversity and the balance of ecosystems just as much as inconvenience people.

Carbon Cycle & Feedbacks

The global carbon cycle is an area where we could use more research along with ongoing (and perhaps accelerated) prudent action. Some research suggests that land reservoirs of CO₂ may be near their limits and of temporary benefit as well. Changes in farming practices could be helpful on this front if carbon can be fixed into the soil.

There is an as yet undetermined risk that the global warming started by human greenhouse gas emissions could start a positive feedback of CO₂ and methane release from oceanic clathrates and Arctic permafrost areas. A positive feedback effect is possible if warmer temperatures melt Arctic permafrost thus releasing CO₂ stored in peat bogs. As sea ice melts, the lowering albedo of the Arctic Ocean represents another positive feedback. These scenarios could double or triple the currently expected warming and have a more grave effect on human and other lifeforms than is already expected. This possibility should be considered in the "risk assessment" of how aggressively to act in reducing our greenhouse gas emissions. In the past few years methane has been leveling off, though it remains elevated above background levels enough to contribute about 1/3 of the radiative forcing compared with CO₂. We'll have to watch carefully for changes in that trend.

Note with the oceans that as the water warms it would be less able to absorb CO₂ keeping more in the atmosphere producing some positive feedback. What CO₂ does get absorbed in the oceans makes it more acidic thus threatening marine life. As the oceans circulate they will eventually come to a CO₂ balance with the atmosphere halting additional uptake. We then have to wait thousands of years for geological processes to kick in that would incorporate CO₂ into rock formations.

Solutions & Long View

My solutions would be a number of things - two that aren't talked about too much are global population reduction and acceleration of hydrogen fusion research. Biofuels that can store carbon in the soil (via pyrolysis) are also intriguing as they could potentially help reverse global warming. The varied mix of concurrent solutions could be the subject of another writeup - the main point being that one has to weigh costs vs. benefits in the face of a good if imperfect prediction. How fast would a prudent response be? My rough estimate would be converting to at least 10% renewable (non-polluting) fuels by 2010, 20% by 2020, on up to 100% by 2100. This would still end up giving us several degrees F warming this century, though at least it might be an achievable way out of this conundrum. If we can completely phase out greenhouse gases earlier, say by 2060 or so, this could give us a more comfortable margin of safety.

It is true that solar forcing could tend to produce an ice age over the next couple of thousand years since the earth's perihelion occurs while the sun shines over the reflective Antarctic ice cap. This may be a mild ice age since the Earth's orbit is more circular these days. However, the amount of human caused global warming appears to be considerably more that what would be needed simply to prevent a future ice age (i.e. too much of a good thing).

Taking a longer view, the current CO₂ level (as augmented by fossil fuel burning, etc.) is shown by ice core samples to be the highest in over 600,000 years. Other evidence leads to a best guess that it is now the highest in tens of millions of years. We thus appear to have pushed the earth's atmosphere into a state it hasn't seen since hominids started walking the planet. Taking the really long view, warming will happen in a billion years anyway as the sun consumes its fuel and heats up

if we haven't decided to move the earth farther away. It's also interesting to note that in earth's distant past (billions of years ago) we actually needed the much greater CO2 (and methane) amounts that then existed to compensate for the fainter young sun. CO2 was still very high (with a warmer climate) when dinosaurs walked the earth. Higher values in the present era would not be so helpful for currently existing lifeforms.

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P.S. More info in the "Global Warming" section of my weather links at:
http://laps.noaa.gov/albers/bookmarks_wx.html