Some Thoughts on Global Warming

Hugh E. Willoughby, E&E, FIU

The existence and implications of Anthropogenic Global Warming (AGW) have taken on much of the acrimony of early 21st Century US politics. Is AGW "settled science" or "a flawed theory perpetrated by grant hungry elitists"? In our view, it is neither. It is a scientific theory, supported by a significant body of convincing evidence. As such, its validity is to be judged by effective responses to well-framed criticism. Some of the more cogent criticisms of AGW are:

1. There does seem to be a solar-climate connection, perhaps explainable by chance, perhaps not. It's a loose end that needs tying up.

2. In terms of ad hominem arguments, Both Dick Lindzen and Roy Spencer are examples of thoughtful critics. Other critics seem to have devolved to unreasoning opposition. A similar judgment might be levied against the more extreme AGW enthusiasts.

3. AGW promoters have consistently advanced a faster timeline than is physically likely and (consequently) argued for more immediate severe effects. This shortcoming is particularly noticeable among those with stronger focus on advocacy than on physical science.

4. A similar shortcoming is attribution of every episode of unusual weather to AGW.

Despite these (somewhat) valid points, many skeptics lack understanding of cloud/ice-albedo feedbacks and of radiative convective equilibrium.

The present climate [post late Pliocene (Piacenzian, 2.9 MYA)] is unusual because of the presence of ice caps at both poles. The ice itself and maritime stratocumulus clouds that both surround it and form over western costal upwelling increase albedo, thus cooling the planet. Externally imposed cooling (due to orbital variations or CO_2 decreases, for example) increases the extent of ice, snow, and cloud---leading to further cooling, and conversely for externally imposed warming.

Note that CO_2 follows temperature during glacial/interglacial cycles because the forcing arises from changes of the distribution of incoming radiation. CO_2 and albedo logically follow these forcings, even though both responses are positive feedbacks that strengthen the thermal response to forcing. In AGW, humans are pushing on the CO_2 link in the cycle so that positive cloud- and ice-albedo feedbacks are essential to troublesome responses that will, in that case, follow the CO_2 fluctuations.

In the tropics and middle latitudes, the Tropospheric vertical temperature profile is determined primarily by convection and the Stratospheric profile by radiation. The Earth radiates as a (more or less) black body at 255K, emitting on average 240 W m^{-2}. This temperature corresponds to an altitude of 5-7 km, depending upon latitude. Most of the H_2O (the primary greenhouse gas) in the atmosphere lies blow the radiative equilibrium (255K) level. Only about 20% of the infrared radiation to space originates at the Earth's surface. Thus, adding CO_2, CFCs, CH_4, or any other greenhouse gas that mixes above the present 255K level, increases the optical depth. The 255K isotherm then has to rise to a higher altitude (Lindzen and Emanuel 2001). Since the convectively determined lapse rate, γ, is a strong constraint on the profile

below the tropopause, the surface temperature increases according to $\Delta T_{sfc} = \gamma(Z_{new} - Z_{old})$, where Z_{new} and Z_{old} are the altitudes of the 255K level after and before the addition of greenhouse gasses. Given that the standard atmosphere lapse rate (6.5°C km^{-1}, γ) is a reasonable estimate of convectively determined vertical profiles, the extrapolated 22nd Century warming (5°C) requires only a 780 m rise of the 255K surface (Fig. 1).

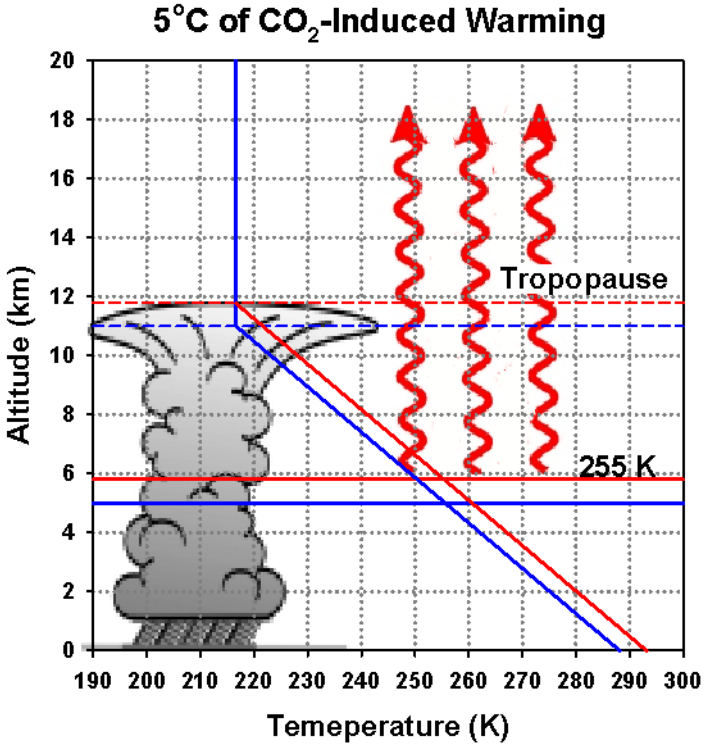

Fig. 1. The effect of doubling atmospheric CO_2. Blue indicates the present vertical temperature profile and red that after doubling CO_2. The 255K level and Tropopause height rise by 780 m to decrease the optical depth above the radiative equilibrium level enough to allow 240 W m^2 of IR radiation to escape to space. Convective adjustment below the 255K altitude warms the surface by 5°C.

Global Climate Models (GCMs) have some limitations. Chief among them are challenges with representing ocean circulations (both wind-driven and thermohaline) and the need to parameterize convective transports and surface properties (moisture, vegetation, albedo, etc.). Nonetheless, current GCMs, as described by IPCC 2007, are much improved over GCMs of a generation ago. They also provide somewhat less support for the more catastrophic prophesies that we hear from AGW promoters. Nonetheless, physically based models are unanimous in predicting substantial warming in response to increasing CO_2.

A few more cycles of Moore's law will give us enough computing power to resolve convective processes. At about the same time, representation of both the oceans and surface characteristics should become more realistic. It's not unreasonable to imagine that model predictions useful for guiding local and regional policy decisions will precede the arrival of severe AGW impacts by decades. Our prejudice is that AGW impacts will come more slowly and be somewhat less severe than most people expect, consistent with the evolution of predictions as the models have become more physically sophisticated.

That said, before the middle Pliocene the climate was much warmer than the present, CO_2 levels may have been as high as 400 ppm(v), and the sea stood 25 m higher. Closing of the Isthmus of Panama, combined with earlier opening of the Southern Circumpolar Ocean, led to increased salinity in the Atlantic, a stronger thermohaline circulation and accelerated formation of North Atlantic Deep Water in addition to Antarctic Bottom Water. High latitude sinking of cold water reduced atmospheric CO_2, enhanced maritime stratus, and increased polar ice and snow cover. These effects amplified radiative forcing due to changes in the planet's orbit, resulting in Pleistocene glacial/interglacial cycles.

The resulting climate is unusual compared with those of the Tertiary or Mesozoic, but it is also the climate within which our civilization developed. 21st Century capitalism, for all its ability to raise people from poverty, rewards efficiency and optimization over the short term---generally at the expense of resource conservation and resiliency against external shocks. On the optimistic side, technological transformations in the post-industrial-revolution world seem to take 50-60 years (e.g., Wright Brothers to Boeing 707), whereas the timescale for AGW is arguably a century or longer. We have within our grasp the ability to plan for the projected future and to leave to our great^{n} grandchildren a habitable world, an enviable standard of living, and a rich and diverse cultural heritage. Even so, will a world with 10^{10} people be able to cope with resource depletion, rising sea level, and an increasingly unreliable hydrologic cycle?

Anthropogenic Global Warming may become the greatest human catastrophe in history. The twin pitfalls of denying the problem and exaggerating its severity or speed of arrival do not serve a rational discourse.

Reference:

Lindzen, R. S., and K. A. Emanuel, 2001: Greenhouse Effect. In *Encyclopedia of Global Change*. Oxford. Univ. Press, New York, pp. 562-566.