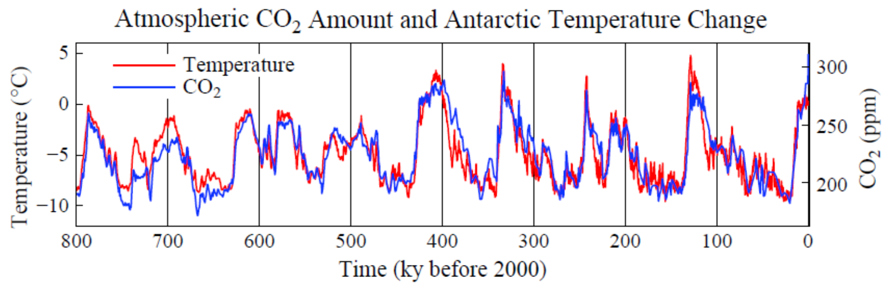

Chart 30. Atmospheric CO_2 amount (Luthi et al., 2008) and Antarctic air temperature change (Jouzel et al., 2007) during past 800,000 years.

Taiwan Charts: CO_2 Control Knob

03 October 2018

James Hansen

A talk ('Young People's World: Making Your Future') that I gave last week to select high school students in Taiwan is available here, including comments on each chart.

Chart 30 of my presentation shows the tight control CO_2 exerts on atmospheric temperature. The temperature in Chart 30 (Jouzel et al., 2007) is obtained from the same Antarctic ice core as the CO_2 amount (Luthi et al., 2008), so it is a regional temperature anomaly. Because of the polar amplification of glacial-interglacial temperature, global temperature change is estimated to be about a factor of two smaller than the polar temperature change.

Chart 31 (below) is a new figure, comparing CO_2 and global mean temperature change inferred from Zachos et al. (2001) ocean core data for the oxygen isotope, $\delta^{18}O$. Ocean cores add a dating uncertainty, relative to the ice core time scale for CO_2, as well as approximations in extracting surface temperature change from $\delta^{18}O$ change, yet the results in Chart 31 tend to reaffirm the tight control of CO_2 on global temperature. This tight control by CO_2 occurs at the temporal resolution of the data, which is typically several centuries at best.

Chart 31 also includes modern data on the right at high temporal resolution, i.e., with the time scale expanded.

Global temperature today is rising, but it has a long way to go to catch up with CO_2. It will catch up, if CO_2 stays at its current level long enough. The time needed for temperature to catch up to CO_2 depends on the ocean surface response time and the ice sheet (and thus sea level) response time.

Ocean surface temperature response (to a global climate forcing, i.e., an imposed planetary energy imbalance) is about 75% complete in 100 years. That estimate is based mainly on the rate at which Earth is observed to be returning toward energy balance in response to the human-imposed planetary energy imbalance, as discussed in Section 3 of our 'Ice Melt' paper.

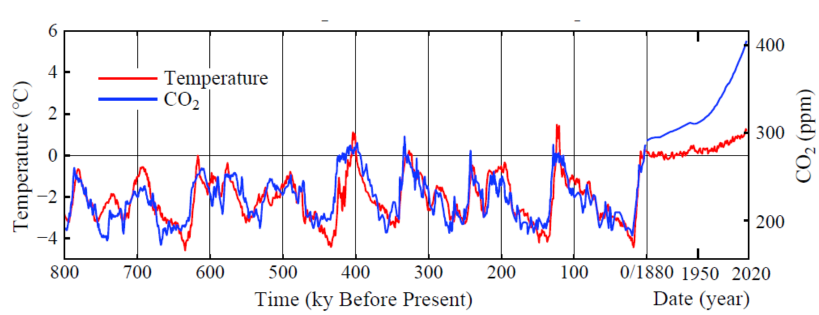

Chart 31. Atmospheric CO_2 from Antarctic ice cores (Jouzel et al., 2007) and modern NOAA measurements, and global surface temperature change estimated from ocean core data of Zachos et al. (2001) using an approximation described in our 'Climate Sensitivity' paper for converting ocean core $\delta^{18}O$ to surface temperature.

Ice sheet response time is more uncertain. Grant et al. (2014) find that sea level change lags 1-4 centuries behind temperature change in paleoclimate data. Ice sheet response time to human-made forcing may be different, because the human-made climate forcing is changing much more rapidly than the slow paleo forcing change.

This slow climate response is both our best friend and worst enemy. It allows time to get atmospheric composition back to a level consistent with a livable planet before the full response to the forcing occurs. However, the slow response also makes it harder for humanity to fully appreciate what we are doing to the planet. As a result, severe consequences for young people could be almost locked in, as discussed in our paper 'Young People's Burden'.

CO_2 is not the only important human-made forcing, but to first order the positive forcing by non-CO_2 greenhouse gases is offset by the negative forcing by human-made aerosols. The most useful quantitative assessments now start with Earth's present energy imbalance and consider the changes to energy balance caused by further changes of the forcings. CO_2 changes are now the overwhelming cause of ongoing changes to Earth's energy imbalance, as shown in our 'Young People's Burden' paper and many other papers.

CO_2 at 350 ppm would yield global warming about +1°C relative to pre-industrial. The appropriate target for CO_2 is still '<350 ppm'. Optimum CO_2 is likely somewhat less than 350 ppm, but greater than 280 ppm. Humans are causing several negative forcings that will continue. Roads, buildings, agricultural fields replacing forests, dust that people will be kicking up even if we eliminate fossil fuel aerosols – these will not be going away.

By the time humanity is able to decrease CO_2 close to 350 ppm we will have much better knowledge of the optimum value for CO_2 amount. Empirical data, especially Earth's energy imbalance, will help us assess how we are doing in the task of stabilizing climate.

References noted here are all given in the papers linked here, which are also on my website.