Is global warming really due to human activity? 11.3.2007

1 CO_2 and temperature

1. It is clear that the CO_2 and the mean Earth temperature are correlated (see the blue and the green curves in figure 1).

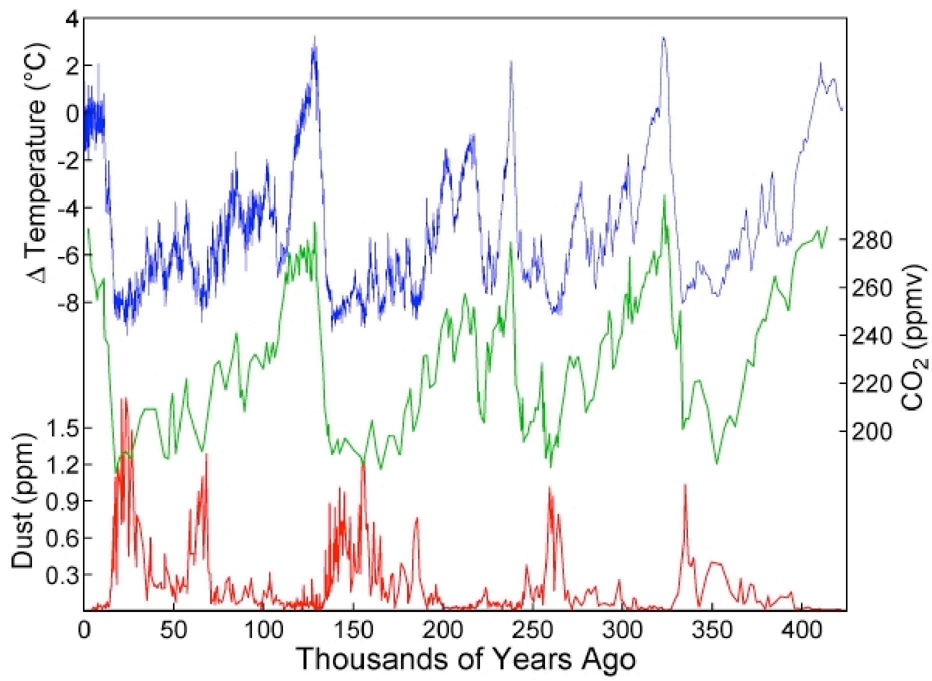

FIGURE 1— Vostok ice cores

2. The **real** problem is: Which one is the cause of the other?

At first, there seem to be two possibilities:

a) CO_2 increase $\longrightarrow$T increase. It could happen through an increased greenhouse effect. In that case, we are directly responsible for the T increase since we are the cause of the CO_2 increase (from 1850 to 2000, CO_2 concentrations went from 290 ppmv to 370 ppmv, where as for the last 1000 years it was around 280 +/- 5 ppmv). (see Figure 2)

b) T increase $\longrightarrow$ CO_2 increase: It could happen through feedback mechanisms involving the amount of vegetal and animal life on Earth. In this case, the increase in T is due to external (astronomical) causes, and not to humans.

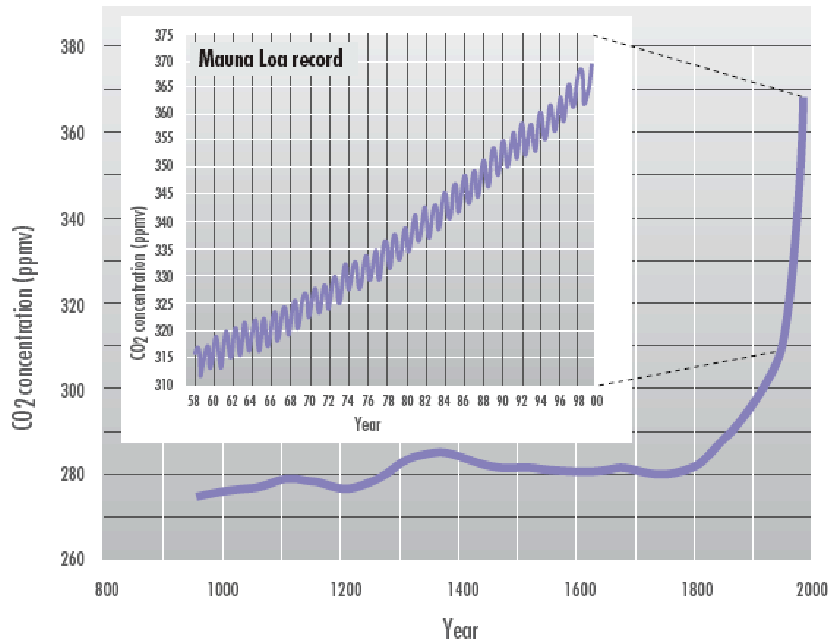

Figure 25. The change in the atmospheric concentration of carbon dioxide over the last 1000 years, based on ice core analysis and, since 1958, on direct measurements. Inset is the monthly average concentration of carbon dioxide (in parts per million by volume) since 1958 at Mauna Loa, Hawaii.

FIGURE 2— CO_2 concentration over the past 1000 years

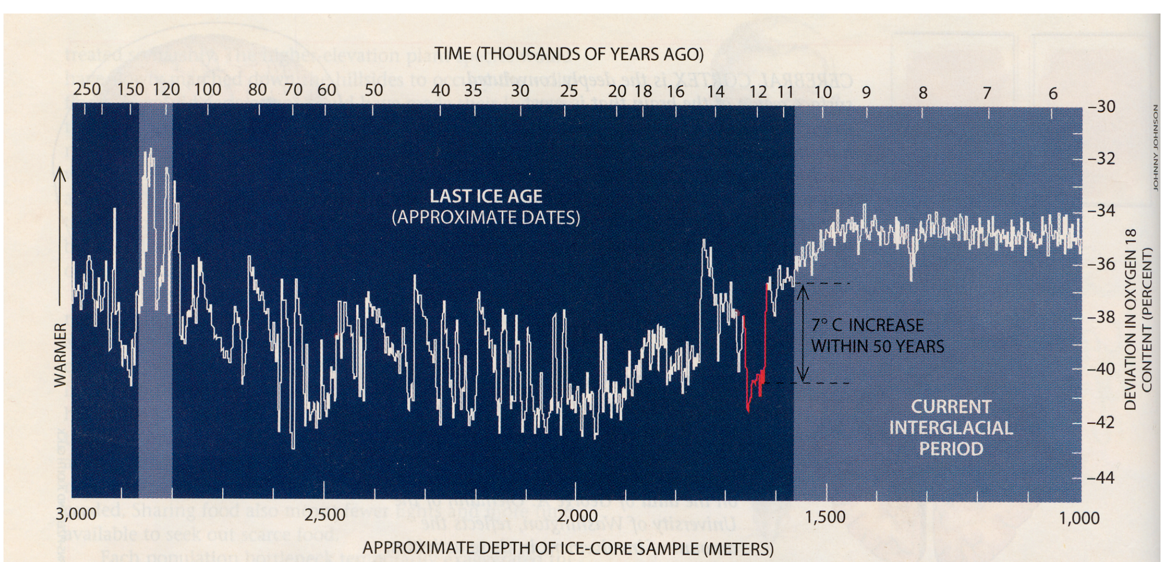

FIGURE 3— Temperature profile over the last 150′000 years

The (natural) astronomical causes that "modeled" the climate over the last million years were responsible for temperature variations of 8 °C between the warm and cold periods, glacier and inter-glacier periods. At the same time, the CO_2 concentrations oscillated between 200 - 280 ppmv (see Figure 1 and 4).

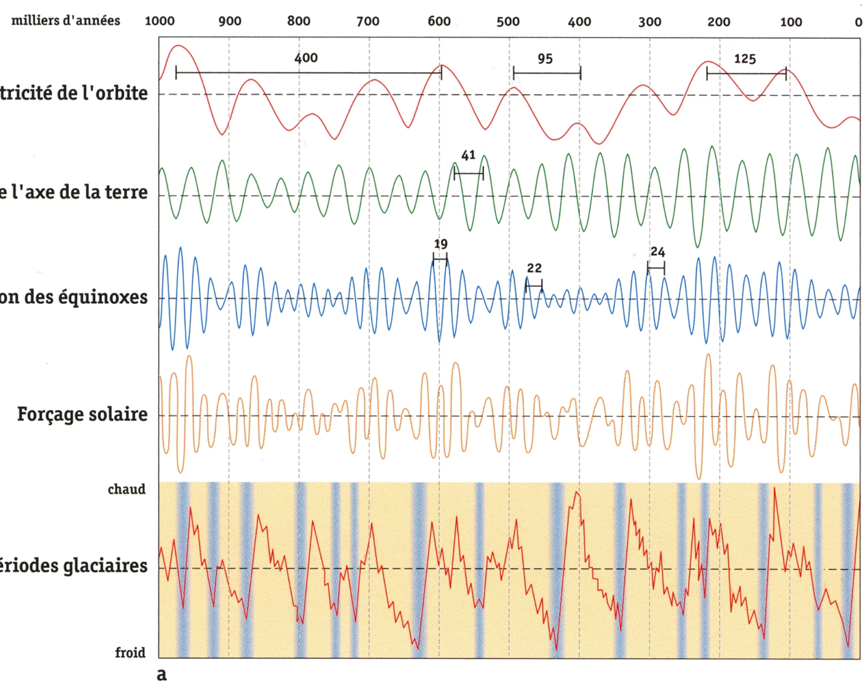

Fig. 3.
a. Evolution des températures à la surface de la terre et cycles des périodes glaciaires pendant le dernier million d'années. Les paramètres astronomiques de Milankovitch.
b.La variation de l'excentricité de la rotation de la terre autour du soleil est responsable de cycles de température de 95 000, 125 000 et 400 000 ans.
c. La variation de l'obliquité de l'axe de rotation de la terre est responsable de cycles de température de 41 000 ans.

FIGURE 4— Temperature profile over the last million years

These ice-age cycles are relatively well understood in astronomical terms: cyclic variations of Earth orbit ellipticity, Earth inclination angle and equinoxes precession (Milankovitch parameters) change the amount of solar light that the Earth receives and therefore change the climate (see Figure 4). Feedback mechanisms are nevertheless required to explain the full range of temperature variations (see Wikipedia article).

Given this regularity, one would expect that external factors are responsible for Temperature changes between +2 and -8 °C (relative to today) and CO_2 changes between 200 and 280 ppmv.

The present concentrations of CO_2 (370 ppmv) are certainly due to human activity for three reasons: First, over the past million year, it has never been so high, even during periods of time equally warm than today. In other words, in the last million years natural causes never generate such high CO_2 concentrations. Second, CO_2 concentrations started to increase dramatically around 1850, the beginning of industrial revolution, which does not seem like a coincidence. Third, the carbon in the CO_2 has different isotopes, and the percentage of these isotopes has changed because fossil fuels contain different percentages than the carbon initially present in the atmosphere. The observed change in isotope composition is in agreement with what is expected for addition of fossil fuels. There has also been a decline of oxygen observed, consistent with the production of CO_2 by burning fossil fuels with oxygen from the air. CO_2 is slightly more abundant in the Northern hemisphere because many more people live in the Northern hemisphere and much more CO_2 is emitted there. The difference in the concentration between North and South is small because it takes only about one year for the emitted CO_2 to be well mixed among both hemispheres.

Due to the correlation CO_2 - Temperature, can we expect a strong global warming?

In the past million years, warm and cold (ice ages) periods had a difference in CO_2 of 100 ppmv (see Figure 1) over a time-scale of 100'000 years. Since 1850, i.e., in less than 200 years, we have added 80 ppmv and this value is still increasing! Note that the little ice-age (around 1850) and the warm medieval period (1000-1300) where the range in temperature variation was 1.5 °C (see Figure 5) are correlated with modest variations in CO_2, at most 10 ppmv (Figure 2). The answer to the above question depends if it is the CO_2 variation that cause the T variation or the other way around.

If the T increase is **not caused** by a CO_2 increase but by other (e.g. astronomical or feedback) factors, how should we interpret the facts presented here? We are in a temperature "peak" period, like those +2 degrees above $\Delta T = 0$ that occur (naturally) at the end of each ice age, see Figure 1. The observed increase in CO_2 is indeed due to us but does not have a major impact on the temperature.

However, given the regularity of the temperature curve, one could expect to be (today) towards the **end** of the usual 10-20'000 years of interglaciar periods (our climate in the recent 12'000 years has been warm and stable, see Figure 3 and 1. Therefore we should, if the climate would be governed only by external cyclic events, go towards a new cold period, which is the opposite trend that what is observed.

2 Conclusion

How do we know the effect of the CO_2 increase? by calculating it. The computer simulations that predict the global weather trends are (at the moment) our only hope to solve this highly complex problem; complex because non-linear, because small details can have a large-scale effect (the famous butterfly effect) and because it includes many aspects of science: physics (energy exchange, fluid, thermodynamics, astronomical orbital parameters), chemistry (chemical reactions in the atmosphere, in the oceans), biology (impact of plants and animals). Various independent groups in the world are using the best super-computers to build such models. They all have slightly different codes and treat the various components in slightly different manners, but they all agree on the main results: in the next century, the Earth mean temperature will increase by 3.5 ($\pm$ 1.5) degrees (Figure 6). No models show a decrease in temperatures!

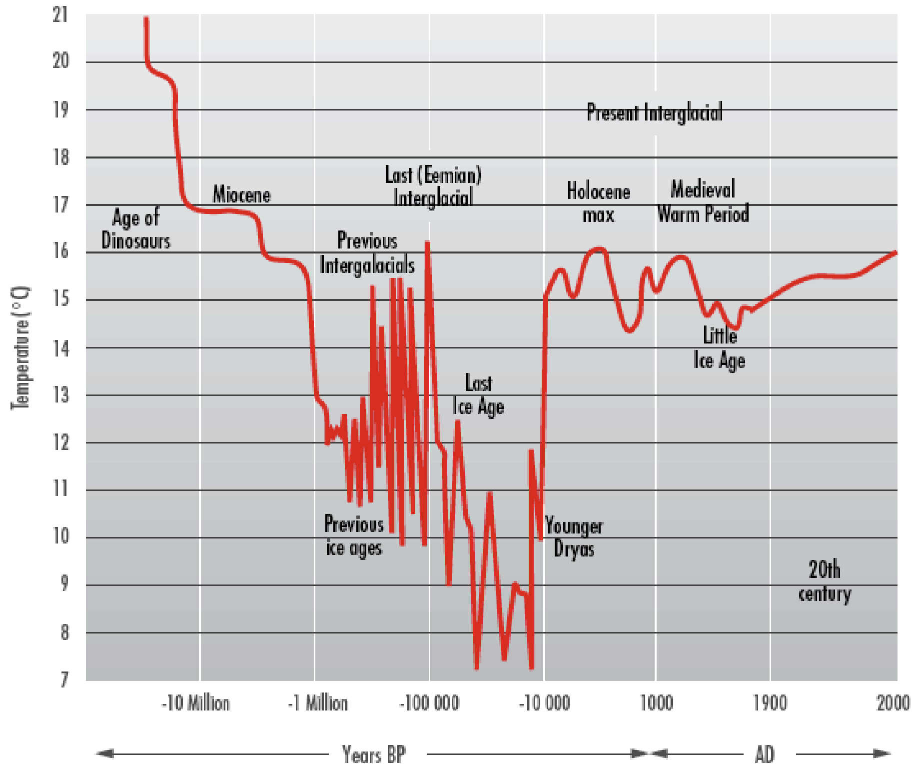

Figure 51. A schematic summary of recent climate trends in historical perspective. The 20th century is shown in linear scale. Earlier periods are shown in terms of increasing powers of ten but are linear within each period.

FIGURE 5— Temperature profile over the last 10 million years

3 Appendix

Why is water vapor, the most important greenhouse gas, not changed by human activities?

Contrary to all other greenhouse gases, water vapor has a very short lifetime in the atmosphere. It constant evaporates from the ocean and wet land, forms clouds, and rains. After evaporation, water typically spends only about two weeks in the atmosphere before it rains. Any additional water vapor that could be produced by humans would rain down in a short time. The amount of water vapor in the atmosphere is at an equilibrium point that depends on the global temperature of the Earth. If the planet warms up, there will be more water vapor. This is because the concentration of water vapor that you need to start condensation into water droplets increases with temperature. The abundance of water vapor is highly variable across the world, because it does not mix through the atmosphere in the short time it spends there. It takes about one year for the atmosphere of the Earth to get well mixed. The other greenhouse gases have lifetimes much longer than a year and are well mixed (see

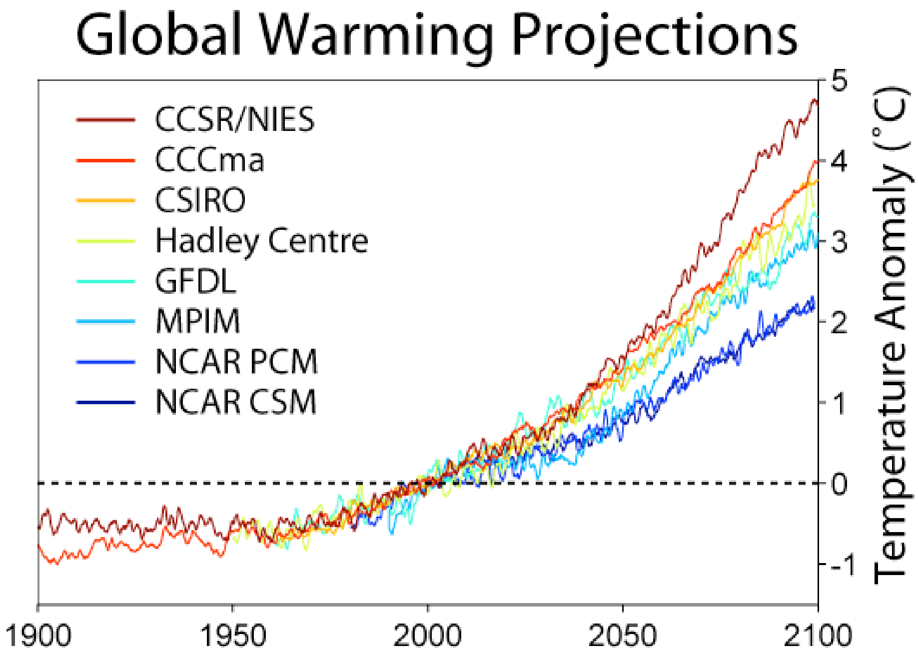

FIGURE 6— Mean temperature projections for the next 100 years.

http://segre.ieec.uab.es/miralda/fsgw/lect3.html)

Are CO_2 measurements reliable data?

Trapped gases in ice-core bubbles are highly reliable records of atmospheric composition, as indicated by comparisons among cores from different ice sheets, and comparison with instrumental records and the air in the firn[1] above the bubble-trapping depth. The slight differences between bubble and air composition caused by gravitational and thermal effects are well understood and recognizable.
(see http://scienceweek.com/2004/sb040820-2.htm)

[1]The "firn" is the zone of porous snow and ice above the closeoff depth, and the depth interval in which bubbles close is termed the "firn-ice transition." Below the transition, densification continues by the compression of bubbles due to hydrostatic pressure.