The world at 4°C: last call on climate

A warning from the past and a blueprint for an emergency CO2 draw-down effort

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"We're simply talking about the very life support system of this planet." (Joachim Schellnhuber, Director, Potsdam Climate Impacts Institute, advisor to the German government).

At 389 ppm CO2 the energy level of the atmosphere has reached a range consistent with recent warm geological periods in the history of Earth (early to mid-Pliocene 5.2–2.8 million years) when CO2 concentration rose to c. 350 - 410 ppm, global temperatures were about 2.4–4.0 Celsius above the 18th century and sea levels were 25+/-12 meters higher than at the outset of current global warming. Since the 18th century the rise of polar temperatures by 3 to 4 degrees C, inducing advanced melting of the Arctic Sea ice, Greenland and west Antarctic ice sheets, is tracking toward similar conditions as the mid-Pliocene. The rise in sea level from c. 1 mm/year early in the 20th century to c. 3.5 mm/year suggests climate change lag effects are accelerating. Deep cuts in emissions of several percent per-year and global application of clean energy technologies, accompanied with a massive emergency program including draw-down of atmospheric CO2 through fast-track reforestation, biochar and chemical sequestration, may have a chance of mitigating runaway climate change.

With greenhouse forcing rising at a geologically unprecedented rate of 2 ppm CO2/year, excepting CO2 release associated with major volcanic events and extraterrestrial impacts, and polar temperatures (3 to 4 degrees C) (Figure 1) tracking toward early to mid-Pliocene-like conditions (c.5.2-2.8 million years-ago; c. 350-410 ppm CO2; c. 2.4 – 4.0 degrees Celsius; sea level 25+/-12 meters) (Figure 2), the atmosphere-ocean system is in unchartered territory, possibly but hopefully not beyond human control. Depending on further burning of the world's fossil fuel reserves of c.6000 GtC (billion ton carbon), the scale of land clearing and deforestation, feedbacks from the carbon cycle and ice/warm water interactions, reduction of the ocean's CO2 absorption capacity and release of methane from permafrost, bogs and shallow sediments, the climate may reach conditions analogous to the Mid-Miocene (sea level 40+/-15 meters) or Paleocene-Eocene Thermal Maximum (PETM) 55 million years ago, when a release of c. 2000 GtC as methane resulted in >5 degrees C temperature rise and the extinction of species.

The potential consequences of a 4 degrees Celsius mean global temperature rise for human habitats defies contemplation. However, a number of emergency measures, when combined, offer a chance of averting irreversible climate tipping points. Should humanity choose to invest its remaining resources in replacement of polluting activities with clean renewable technology, coupled with a massive effort at draw-down of atmospheric CO_2, re-forestation and extensive application of biochar, in preference to a plethora of current activities, primarily war games, a chance exists a runaway climate crisis could still be averted, a choice representing the hour of truth in the short history of Homo sapiens.

Forming a thin breathable veneer, only slightly more than one thousandth the diameter of Earth and evolving both gradually as well as through major perturbations, the Earth's atmosphere acts as a lungs of the biosphere, allowing an exchange of carbon gases and oxygen with plants and animals which, in turn, affect the atmosphere, for example through release of photosynthetic oxygen and methane. As testified by the geological record nearly all of the previous mass extinctions of species through the history of Earth have been associated with a rise in CO_2, methane and/or H_2S, injection of aerosol and dust, acidification of the oceans and anoxia (Stanley, 1987; Ward, 1994, 2007; Sepkoski, 1996; Keller, 2005; Zachos et al., 2001, 2008; Glikson, 2005, 2008; Veron, 2008).

The concentration of greenhouse gases in the atmosphere exerts radiative forcing which modulates temperatures and, in turn, generates feedbacks from the hydrosphere and the biosphere. Significant increases in the level of CO_2 gases trigger release of CO_2 from warming water, ice melt/warm water interaction, decline of ice reflection (albedo) and increase in infrared absorption by exposed water. Further release of CO_2 from warming oceans and from drying and burning vegetation shifts global climate zones toward the poles, further warms the oceans and induces acidification (Hansen et al., 2007, 2008; Veron, 2008). The essential physics of the infrared absorption/emission resonance of greenhouse molecules, indicated by observations in nature and laboratory studies, is expressed by the relations between atmospheric CO_2 and mean global temperature projections.

Lost in the climate debate is an appreciation of the delicate balance between the physical and chemical state of the atmosphere-ocean-cryosphere-land system and the evolving biosphere, which controls the emergence, survival and demise of species, including humans. Species capable of adapting to long term environment changes may be unable to survive through runaway climate change and climate tipping points expressed by extreme weather events.

It is not widely realized that, at 389 ppm atmospheric CO_2, or c.460 ppm atmospheric CO_2-equivalent (a value including methane), rising at c.2 ppm CO_2/year, the upper stability limit of the large polar ice sheets, which serve as the Earth's climate "thermostats", has been intersected, affecting the cold humid air vortices (which bring rain to southern Australia) and cold ocean currents (Humboldt, California, west Africa). The transition from the relatively stable to gradually cooling Holocene climate state to climate conditions above 2 degrees C involve increase in the amplitude of the ENSO cycle, a rise in the frequency of the El-Nino and a decrease in the frequency of the La-Nina phases. As recorded for the "*Younger dryas*" (12.900–11.700 years ago) and the "*Holocene Optimum"* (c. 8200 years-ago), global warming was followed by transient drop of temperatures, attributed to the cooling effects of melting ice on the oceans.

Since the 18th century mean global temperature rose by about 0.8^{o}C. Further rises by 0.5^{o}C are masked by industrial-emitted sulphur aerosols. The most detailed satellite information available shows that ice sheets in Greenland and western Antarctica are shrinking and in some places are already in a runaway melting mode (http://www.msnbc.msn.com/id/32985250/ns/us_news-environment/). A new study, using 50 million laser readings from a NASA satellite, calculates changes in the height of the ice sheets and found them especially worse at their edges, where warmer water eats away from below. In some parts of Antarctica, ice sheets have been losing 10 meters a year in thickness since 2003 (http://climateprogress.org/2009/10/26/nature-dynamic -thinning-of-greenland-and-antarctic-ice-sheets-glacier/).

Sea level rise constitutes the overall parameter which reflects all other components of climate change. Since the early 20th century the rate of sea level rise increased from about 1 mm/year to about 3.5 mm/year (1993 – 2009 mean rate 3.2+/-0.4 mm/year), representing a nearly 4-fold increase in the rate of global warming since the onset of the industrial age. According to Overpeck et al. (2008) "*Sea-level rise from melting of polar ice sheets is one of the largest potential threats of future climate change. Polar warming by the year 2100 may reach levels similar to those of 130,000 to 127,000 years ago that were associated with sea levels several meters above modern levels; both the Greenland Ice Sheet and portions of the Antarctic Ice Sheet may be vulnerable. The record of past ice-sheet melting indicates that the rate of future melting and related sea-level rise could be faster than widely thought*."

Detailed multi-proxy-based studies of the early to mid-Pliocene (c.5.2–2.8 Ma) (Pagani et al. 2010) and the mid-Miocene (c.14-16 Ma) (Kurschner et al., 2008), when continent-ocean patterns were similar to the present, allow correlations of atmospheric CO2 levels, mean global temperatures, sea levels and other parameters, with implications to current climate change trajectories (Figure 3). During the early and mid-Pliocene expansion of the tropics and migration of the subtropical zones toward the poles extended savannah regions, allowing humans to migrate. Intensified warm ocean currents contributed to warming of high latitude zones and spread of boreal forests toward the Arctic circle. However, under present-day conditions, the drying up of temperate mid-latitude zones, sea level rise and flooding of delta and low river valleys (Figure 4), would deprive the world from the bulk of its agricultural potential.

Estimates can hardly be made of the consequences of related release of thousands of billion tons of metastable methane located in permafrost, shallow sediments and bogs (Figure 5).

Much like a mountain climber suffering from altitude sickness, the world needs to urgently come down from its current CO2 level of 389 ppm, to at least 350 ppm but likely to 320 ppm, before it is too late. Only the deepest cuts in emission accompanied with emergency draw-down of atmospheric CO2 through fast-track reforestation, biochar and chemical sequestration, have a chance of mitigating runaway climate change.

Feeble attempts by civilization to mitigate the climate are drowning in a tide of medieval conspiracy theories by *man-over-nature* ideologues (Hoggan, 2009; Hamilton, 2010). There is nowhere the 6.5 billion of contemporary humans can go, not even the barren planets into the exploration on which space agencies are pouring more funding than governments allocate for environmental mitigation to date. Nor would the discovery of Martian bacteria compensate for the loss of the rainforests and coral reefs.

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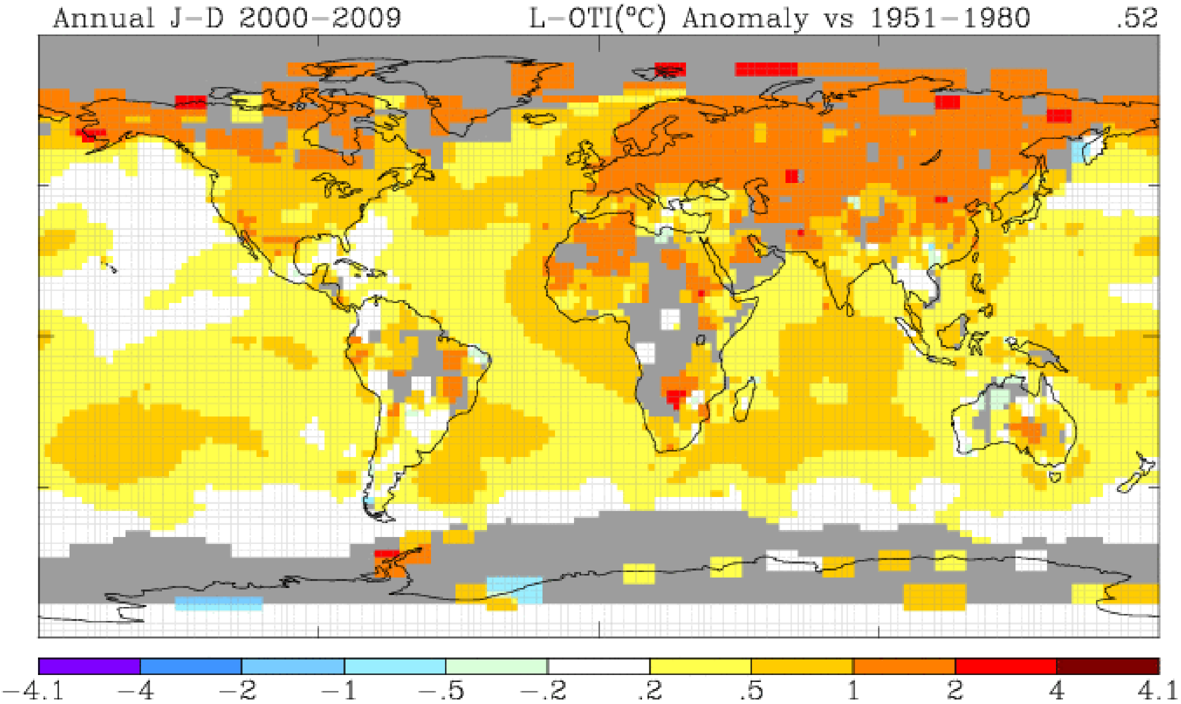


Figure 1

Land (NASA/GISS) and ocean (NOAA) mean annual temperature anomalies for the period 2000-2009 relative to 1951-1980. Anomalies smoothed over 250 km. Note: (1) warming by up to 4 degrees Celsius over parts of the Arctic and west Antarctica; (2) warming of continental mid-latitude dry zones, including central Australia, by about 2 degrees C; (3) warming of large parts of ocean surfaces by up to 1.0 degrees C. Grey areas have no data.
http://data.giss.nasa.gov/gistemp/maps/

Figure 2

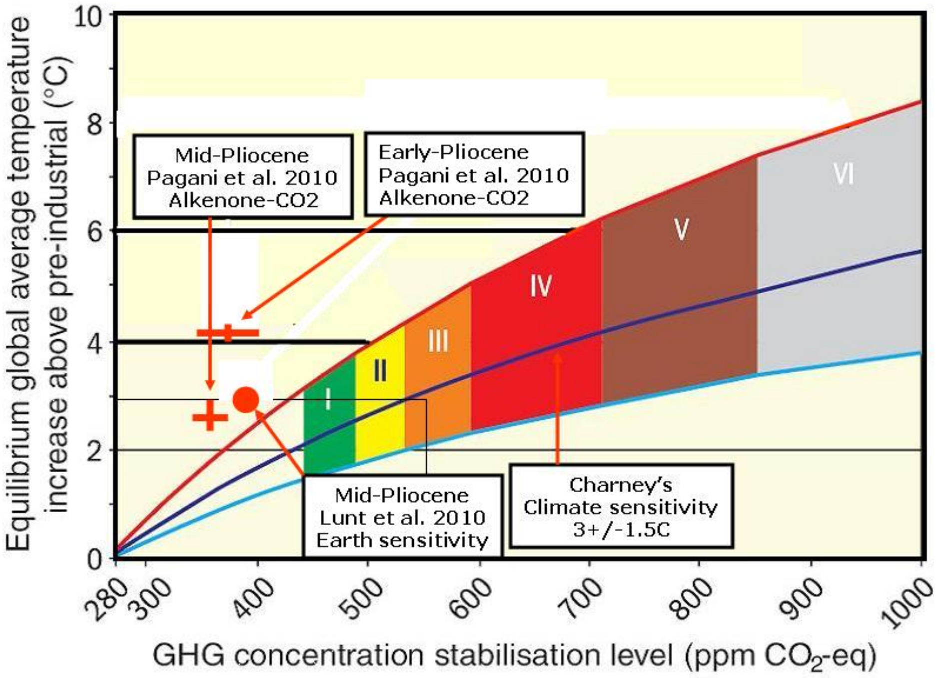


Figure 2

The relations between atmospheric CO2-equivalent (including the radiative forcing of methane) and mean global temperature, according to Charney's climate sensitivity parameter of 3 +/- 1.5 degrees C per doubling of CO2 (Hansen et al., 2007, 2008) (IPCC-2007). The red crosses represent recent CO2-temperature relations based on CO2-alkenone (resistant organic compounds contained in phytoplankton) proxy (Pagani et al., 2010). The Red circle represents estimates of climate sensitivity as a function of longer term vegetation and ice sheet changes (Lunt et al. 2010).

Figure 3A

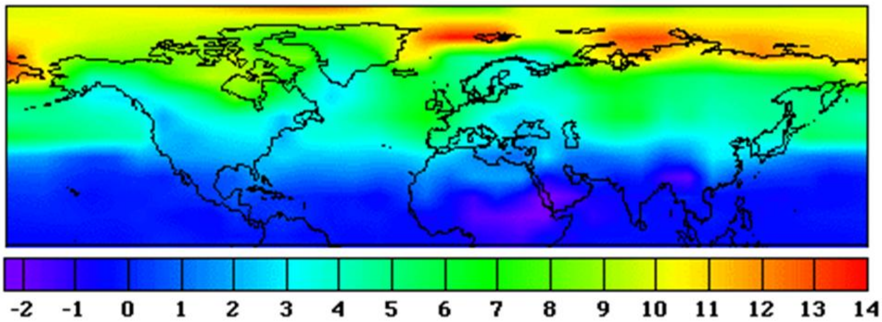
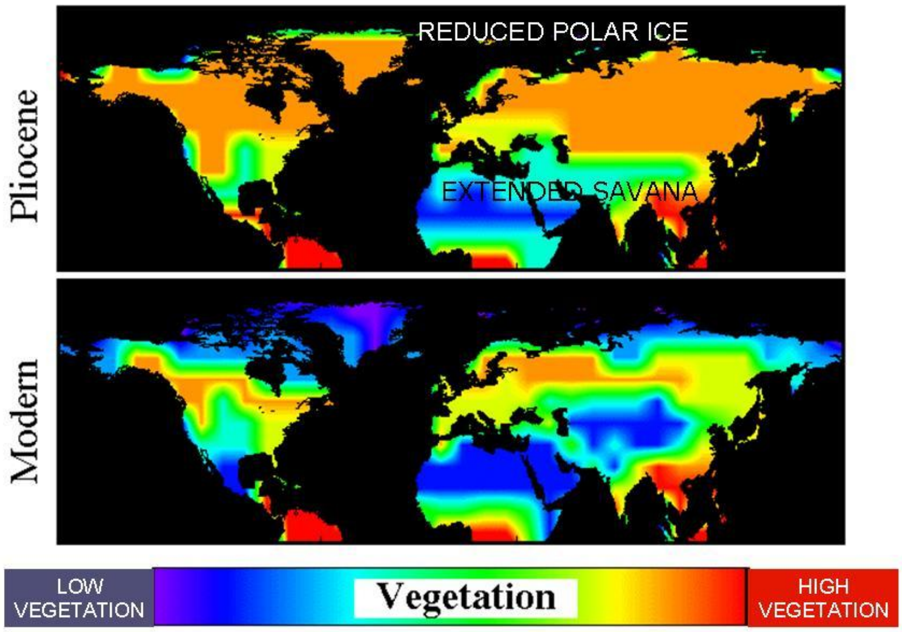


Figure 3B



Pliocene and modern vegetation global albedo distribution.
http://www.giss.nasa.gov/research/features/pliocene/page2.html

Figure 3.

Proxy and model-based paleo-temperature and paleo-albedo maps for the Northern hemisphere mid-Pliocene (3.0–2.8 million years ago) (Chandler, 1997).

A. Mean global paleo-temperatures relative to the present.
B. Albedo maps comparing the mid-Pliocene with the present. Note the reduced polar caps and expansion of savanna in Africa in the mid-Pliocene, of significance in relation to pre-historic human migration, and expansion of deserts in modern times.

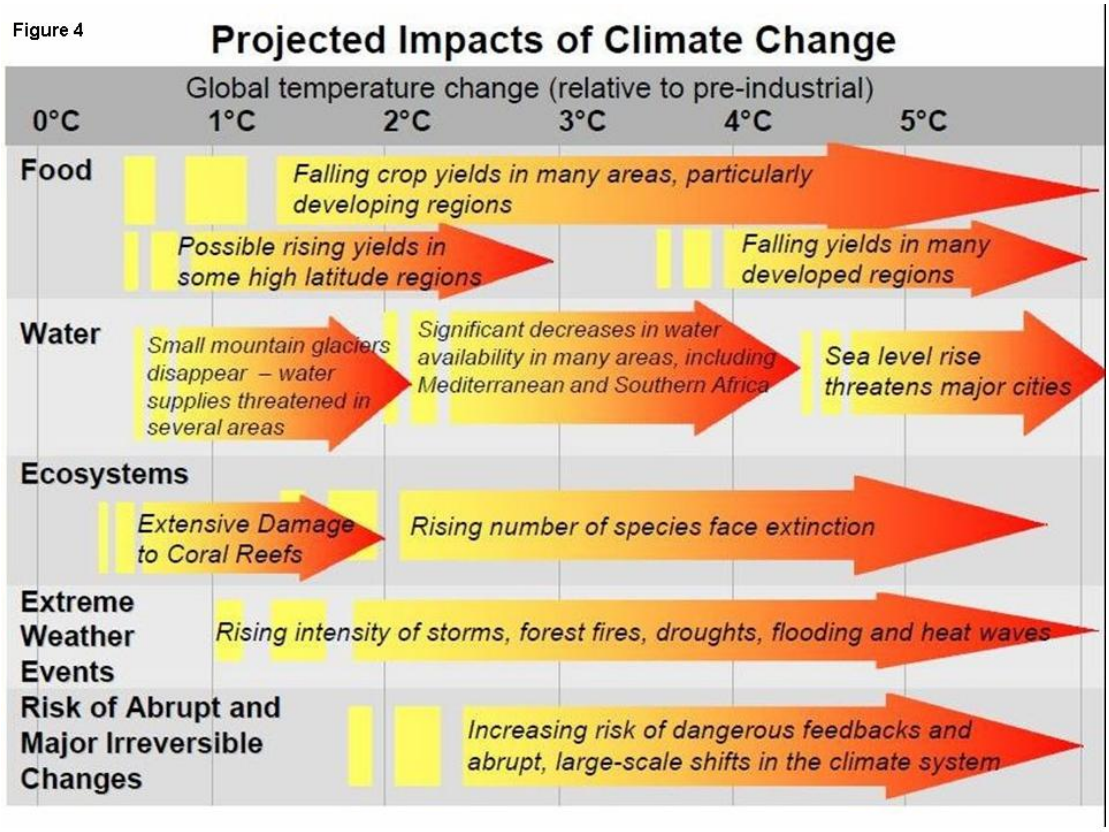


Figure 4

Projected impact of climate change. UNEP/GRID-Arendal Maps and Graphics Library. 2008. Note consequences at 4 degrees C, including decreased water availability and failing crops in temperate zones, increased extreme weather events and feedbacks leading to abrupt shifts in the climate system.

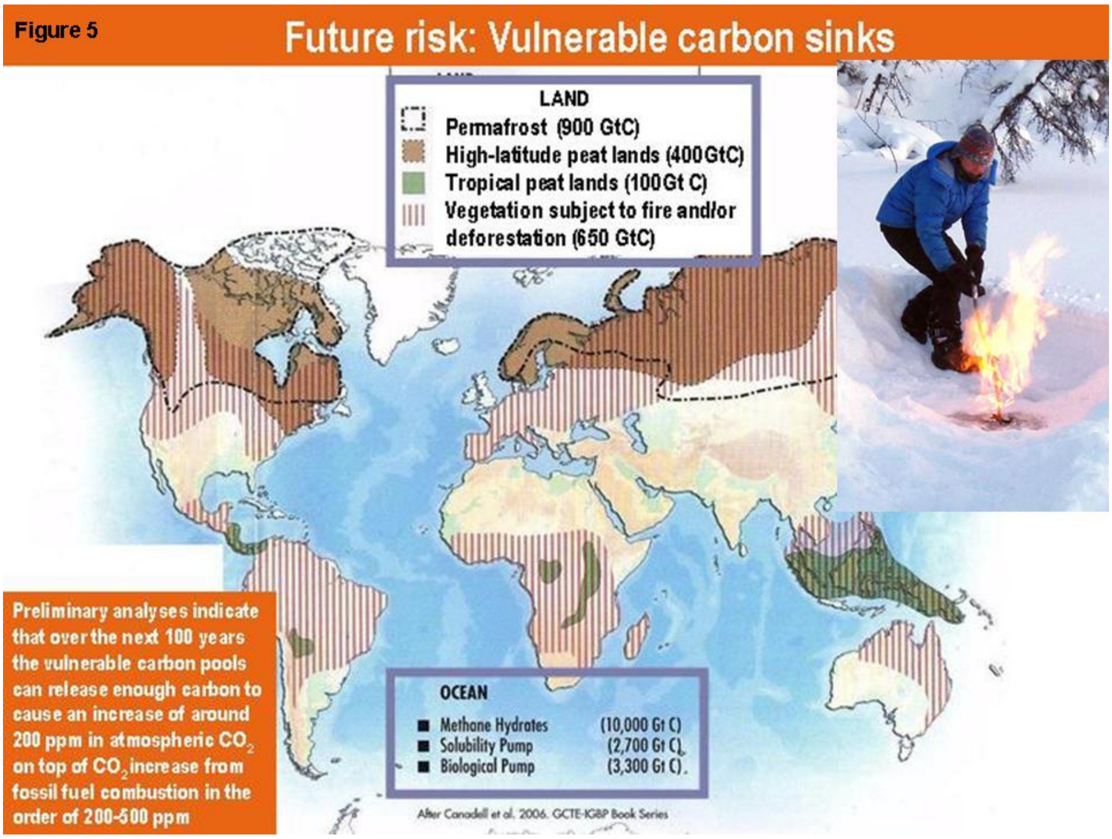


Figure 5

Vulnerable carbon pools in the 21st century. Note the over 1000 billiobn tons (GtC) scale of methane deposits in permafrost and peat lands. Photograph shows burning methane released from an ice covered lake.
http://unesdoc.unesco.org/images/0015/001500/150010e.pdf