Prognosis for a sick planet

Mark Maslin

ABSTRACT – Global warming is the most important science issue of the 21st century, challenging the very structure of our global society. The study of past climate has shown that the current global climate system is extremely sensitive to human-induced climate change. The burning of fossil fuels since the beginning of the industrial revolution has already caused changes with clear evidence for a 0.75°C rise in global temperatures and 22 cm rise in sea level during the 20th century. The Intergovernmental Panel on Climate Change synthesis report (2007) predicts that global temperatures by 2100 could rise by between 1.1°C and 6.4°C. Sea level could rise by between 28 cm and 79 cm, more if the melting of the polar ice caps accelerates. In addition, weather patterns will become less predictable and the occurrence of extreme climate events, such as storms, floods, heat waves and droughts, will increase. The potential effects of global warming on human society are devastating. We do, however, already have many of the technological solutions to cure our sick planet.

KEY WORDS: climate change, global warming

Lessons from the past

Climate change in the geological past provides the context for the current concern regarding human-induced global warming. Various geological records reveal that over the last 100 million years the Earth's climate has been cooling down, moving from the so-called 'greenhouse world' of the Cretaceous period, when dinosaurs enjoyed warm and gentle conditions, through to the cooler and more dynamic 'ice house world' of today.[1] This long-term, 100 million-year transition to colder global climate conditions was driven mainly by tectonic changes. There is also geological evidence that this cooling has been accompanied by a massive drop in the levels of atmospheric carbon dioxide. For example, 100 million years ago during the time of the dinosaurs atmospheric carbon dioxide levels could have been as much as five times higher than today.[2]

These changes culminated in the glaciation of Antarctica about 35 million years ago and the great northern hemisphere ice ages, which began 2.5 million years ago. Since the beginning of the great northern ice ages the global climate has cycled from conditions that were similar today, to full ice ages, which caused ice sheets over 3 km thick to form over much of North America and Europe. These great ice-age cycles are driven primarily by changes in the Earth's orbit with respect to the sun. In fact, the world has spent over 80% of the last 2.5 million years in conditions much colder than the present.[3]

It may seem strange in an article about global warming to suggest that we are currently in a geological 'ice house world'. This is because, despite being in a relatively warm interglacial period, both poles are still glaciated, which is a rare occurrence in the geological history of our planet. Antarctica and Greenland are covered by ice sheets, and the majority of the Arctic Ocean is covered with sea ice. This means that there is a lot of ice that could melt in a warmer world, and, as we will see, this is one of the biggest unknowns that the future holds for our planet.[4]

Reconstructing past climate is essential if we are to put the instrumental temperature records for the last 150 years into context. Global temperature reconstructions for the last 2,000 years using corals, tree rings and ice cores first show that the Little Ice Age of the 17th and 18th centuries occurred only regionally and not globally. It seems the symbolic Ice Fairs on the River Thames were more to do with the sluggish flow of the river prior to the building of the Port of London than the colder temperatures. The 2,000-year temperature record also demonstrates the exceptional nature of the warming observed over the last 100 years, ravelling the so-called 'hockey stick'.

The greenhouse effect

The temperature of the Earth is determined by the balance between energy input from the sun and its loss back into space. Of Earth's incoming solar short-wave radiation (ultraviolet radiation, and that in the

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NEW SERIES

Climate change is a vital issue perhaps overshadowed in recent months by financial turmoil on the international markets. In the longer term its importance may even exceed that of the current financial crisis. This paper is the first in a short series based on talks delivered at the 'Climate change and its impact on health' conference held at the Royal College of Physicians on 29 January 2008

visible spectrum), about one-third is reflected back into space.[5] The remainder is absorbed by the land and oceans, which radiate their acquired warmth as long-wave 'infrared' radiation. Atmospheric gases such as water vapour, carbon dioxide, ozone, methane, and nitrous oxide are known as greenhouse gases. These gases can absorb some of this long-wave radiation and are warmed by it. This greenhouse effect is vital as without it the Earth would be at least 35°C colder. Since the industrial revolution fossil fuels (oil, coal, gas), deposited hundreds of millions of years ago, have been burnt releasing the carbon back into the atmosphere, increasing the greenhouse effect and elevating the Earth's temperature.

Anthropogenic climate change

The first direct measurements of atmospheric CO_2 concentrations started in 1958 at an altitude of about 4,000 metres on the summit of Mauna Loa (Hawaii), a remote site free from local pollution. To extend this record further back air bubbles trapped in ice are analysed. These long ice core records suggest pre-industrial CO_2 concentrations were about 280 parts per million by volume (ppmv). In 1958 the concentration was already 316 ppmv, and this has climbed each and every year to reach 384 ppmv in 2007. This level of pollution caused in one century is comparable to the natural waxing and waning of the great ice ages which took thousands of years.

According to the Intergovernmental Panel on Climate Change (IPCC) the increase in greenhouse gases over the last 150 years has already significantly changed the Earth's climate: average global temperatures have climbed by 0.76°C; the sea level has risen over 40 mm; significant shifts in the seasonality and intensities of precipitation have been experienced; changing weather patterns have occurred; and there has been a significant retreat of Arctic sea ice and nearly all continental glaciers.[4] In the last 150 years the 12 warmest years on record have occurred in the last 13 years: 1998 was the warmest, followed by 2005, 2002, 2003 and 2004. The eighth warmest year on record was 2007. The IPCC stated that the evidence for global warming is unequivocal and there is very high confidence that this is due to human activity.[4] This view is supported by a vast array of learned organisations, including the Royal Society and the American Association for the Advancement of Science.

Future climate changes and impacts

The IPCC synthesised the results of 23 atmosphere-ocean general circulation models (AOGCMs) to predict future temperature rises, based on six emission scenarios.[4] They report that global mean surface temperature could rise by between 1.1°C and 6.4°C by 2100, with best estimates being 1.8°C to 4°C. However, it should be noted that global carbon dioxide emissions are already rising faster than the most alarming of the IPCC scenarios. The models also predict an increase in global mean sea level of between 18 cm and 59 cm. If the contribution from the melting of Greenland and Antarctica is included then this range increases to between 28 cm and 79 cm by 2100. All such predictions assume a continued linear response between global temperatures and loss of the ice sheets. This synchronicity is unlikely and sea level rise could thus be much higher.

The impact of global warming will increase significantly as the temperature of the planet rises.[6,7] The return period and severity of floods, droughts, heat waves and storms will worsen. Coastal cities and towns will be especially vulnerable as the rise in sea level will increase the affects of floods and storm surges.[8] The increase of extreme climate events coupled with reduced water and food security will have a severe effect on the public health of billions of people (Fig 1).[9] Global warming also threatens global biodiversity. Ecosystems are already being hugely degraded by habitat loss, pollution and hunting. The 2007 Millennium Ecosystem Assessment report suggested that three known

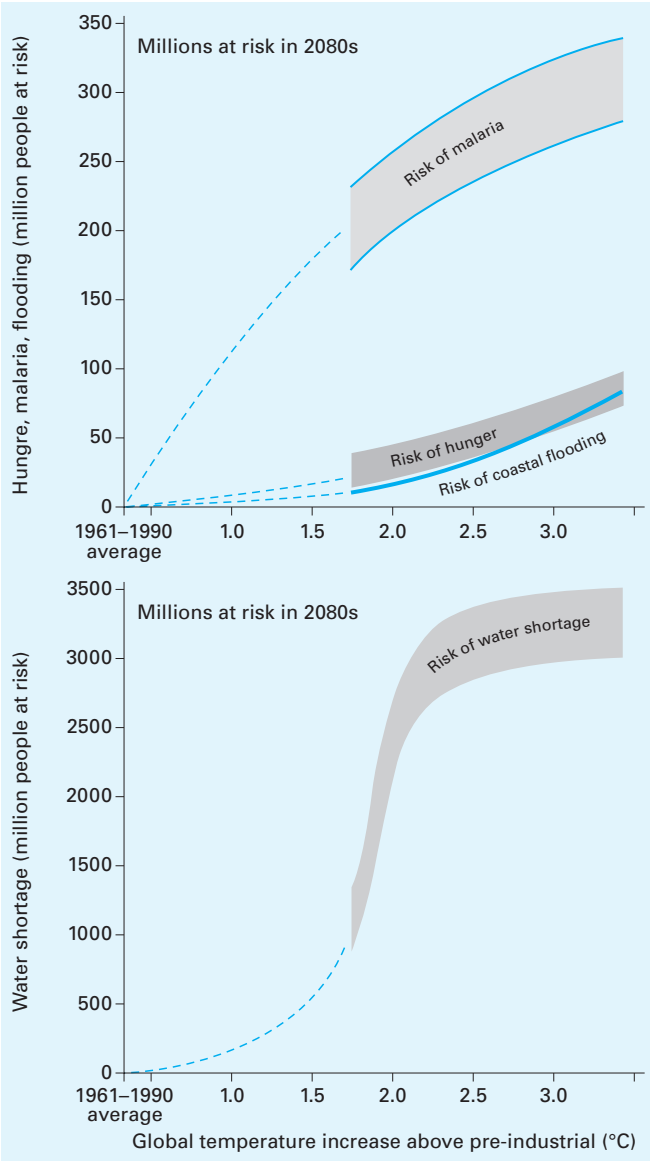

Fig 1. Climate change risks as a function of increasing temperatures.[14] Reproduced by permission of Oxford University Press.

species were becoming extinct each hour, while the 2008 Living Planet Index suggested that the global biodiversity of vertebrates had fallen by over a third in just 35 years, an extinction rate now 10,000 times faster than any observed in the fossil record.[10] Global warming is likely to exacerbate such degradation. Economic impacts, as outlined by Stern, will be severe and mass migration or armed conflict may result.[11]

What is a safe level of climate change?

In February 2005 the British government convened an international science meeting to discuss this topic. Their recommendation is that global warming must be limited to a maximum of 2°C above pre-industrial average temperatures.[12] Below this threshold it seems that there were both winners and losers due to regional climate change, but above this figure everyone seems to lose. However, it now seems likely that temperature rises will exceed this threshold: a rise of 0.76°C has already occurred, and had all emissions been stopped in 2000 there would still have been a 0.6°C rise due to the inertia and feedbacks in the climate system. If the impacts of small temperature rises are profound sustained global temperature rises of 5–6°C would be horrific (Fig 1). Such a rise would lead to the loss of Greenland and the Western Antarctic ice sheets by the middle of next century, raising sea levels by up to 13 m. The UK Environment Agency has plans to deal with a rise of 4.5 m through construction of a barrier across the mouth of the River Thames stretching from Essex to Kent. However, 13 m would mean the flooding and permanent abandonment of nearly all lower-lying coastal and river urban areas. At the moment one third of the world's population lives within 60 miles of a shoreline and 13 of the world's 20 largest cities are located on a coast. Billions could be displaced in environmental mass migration. The North Atlantic Ocean circulation could collapse plunging Western Europe into a succession of severe winters followed by severe heat waves in summer. At least three billion people in the world would be water stressed, billions more would face starvation and the risk of armed conflict would rise hugely.[9] Public health systems around the world would collapse and global biodiversity would be devastated.[9]

What's the cost?

According to the Stern Review if we do everything we can now to reduce global greenhouse gas emissions and ensure we adapt to the coming affects of climate change it will only cost us 1% of world gross domestic product (GDP) every year.[11] However, if we do nothing then the impacts of climate change could cost between 5% and 20% of world GDP every year. These figures have been disputed. Pielke *et al* (2008) have argued the cost of converting the global economy to low carbon could cost more than 1% GDP because global emissions have risen faster than the worst predictions.[13] In response Stern has recently revised his figure to 2%. While some argue that the costs could easily be offset by a global carbon trading system,[14] others suggest that the impacts and the associated costs of global warming have been under-estimated by IPCC and the Stern Report. Even if the cost-benefit of solving global warming is less than suggested by Stern,[11] there is undeniably an ethical case of preventing the deaths of tens of millions of people and the increase in human misery for billions.

Solutions

Global warming is the major challenge for global society. Do not underestimate the challenge ahead. The climate predictions of the IPCC were based on carbon emission scenarios over the next 100 years which were realistic forecasts in 2000.[4] The economic

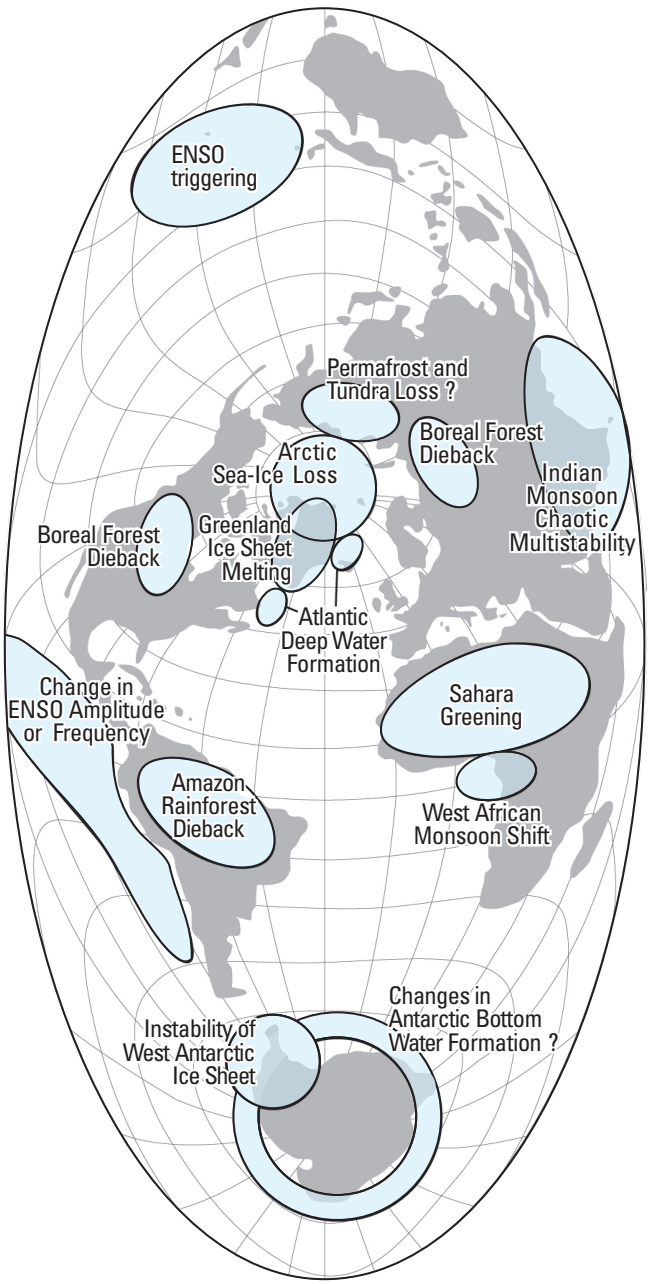

Fig 2. Potential climate change tipping points.[14] Reproduced by permission of Oxford University Press. ENSO = El Niño-Southern Oscilation.

miracle in China, however, will cause carbon emissions to rise 11–13% between 2000–10 instead of the highest estimate used for Asia by the IPCC of 2.6–4.8%.[15] In addition the consensus approach used by IPCC to get agreement of all parties means future climate estimates are inherently conservative.[16] This means that the top estimates of climate change (over 6°C warming by 2100) are more likely. The climate system is also not linear so there will be major tipping points when significant changes occur very rapidly. Figure 2 collates the tipping points which colleagues believe are most likely to happen in the near future and will be most devastating.[14] If we cannot reverse the current global emission trends all of these tipping points will occur in our future.

What are the solutions to global warming? First there must be an international political solution; without a post-2012 agreement we are looking at huge increases in global carbon emissions and devastating global warming. Any political agreement will have to include rapidly developing countries while protecting their moral right to develop and to obtain the same lifestyle we currently enjoy. We also need massive investment in alternative/renewable power sources and low carbon technologies, to provide the means of reducing world carbon emissions.[17,18] We must not pin all our hopes on global politics and clean energy technology, we must prepare for the worst and adapt. If implemented now, much of the costs and damage that could be caused by climate change can be mitigated. This requires nations and regions to plan for the next 50 years, something that most societies are unable to do because of the short-term nature of politics. Global warming challenges the very way we organise our society. Not only does it challenge the concept of the nation state versus global responsibility, but also the short-term vision of our political leaders. To answer the question of what we can do about global warming, we must change some of the basic rules of our society to allow us to adopt a much more global and long-term sustainable approach.

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