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ALARMIST GLOBAL WARMING MODELS VS THE GEOLOGICAL RECORD

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Summary

It is generally assumed that the current trend of global warming is detrimental to humanity and ecosystems in general. However, the geological record clearly indicates that the global ecosystem thrives during greenhouse ages and declines during ice ages, such as the one that we are presently experiencing. These observations on the long-term geological record are never part of the debate on global warming, which is usually constrained to the last few hundred years, or thousands of years at best. Clearly, this does not bring enough perspective, as we have to go back 35 million years to get out of the current ice age, which started with the birth of an ice sheet on Antarctica. Since then, ecosystems have been experiencing tremendous stress due to the gradual deterioration of global climate. The current trend of global warming is but a small notch in a large scale trend of global cooling that started over 100 million years ago. Prior to then, in Early Cretaceous times, the carbon dioxide levels of the atmosphere were more than six times those of today, allowing life to flourish more than it had ever done since the early Paleozoic (i.e., since the previous greenhouse age). The current long-term cooling trend is caused by several orogenic events, which increase the erosional rates of calcium and magnesium from the crust to the oceans, and which therefore promote the long-term storage of carbon into carbonate rocks. Most of these orogenic events are still going on today (Himalayas, Alps, Rockies, Andes, etc.), and the current ice age is therefore destined to keep aggravating… unless we release a sufficient amount of the atmospheric carbon that is presently locked in fossil fuels…

Introduction

The 1997 Kyoto Protocol identified carbon dioxide emissions and their effects on global climate as the main environmental threat to be tackled by modern societies, and environmental activists, such as Greenpeace, also put most of their energy into defeating the same beast. However, from a geologist's perspective, this could be seen as an interesting paradox. In fact, carbon dioxide stands out as the "good guy" in the geological record, and problems show up when there is not enough of it in the atmosphere; not the contrary. Below is the rarely told story of the world's most infamous benefactor.

The origins of carbon dioxide

The carbon and oxygen that compose Earth's #1 greenhouse gas are produced by nuclear fusion in large stars. Following a supernova, these elements can then be diffused into a gas cloud to eventually become involved in planetary accretion. The combination of carbon and oxygen forms a light compound that naturally tends to concentrate in a planet's outermost regions through the process of density segregation that occurs during planetary accretion. In the case of the early Earth, it is not clear if carbon was dominantly associated with oxygen, to form carbon dioxide, or with hydrogen, to form methane

(CH_4) (Pavlov et al., 2003; Kasting, 2005; Kasting and Ono, 2006). In any case, both are greenhouse gases. It is estimated that carbon contents in the atmosphere were three to four orders of magnitude higher at the time of accretion than they are today (Walker et al., 1981; Kuhn and Kasting, 1983; Kasting and Ackerman, 1986; Kasting, 1987, 1993, 1997; Kasting and Siefert, 2002) (Figure 1). They allowed the primitive Earth to maintain a warm climate, although the luminosity of the Sun may have been only 70 to 75% of what it is today (Gough, 1981). Luckily, oceans, organic life and plate tectonic processes participated to the removal of much carbon from the atmosphere and to its long-term storage in sedimentary rocks. Otherwise, as the Sun increased its luminosity, Earth's climate would have soon become too hot for life to exist. For instance, Venus lacks such mechanisms for carbon dioxide removal, and its atmosphere is at the fusion point of steel.

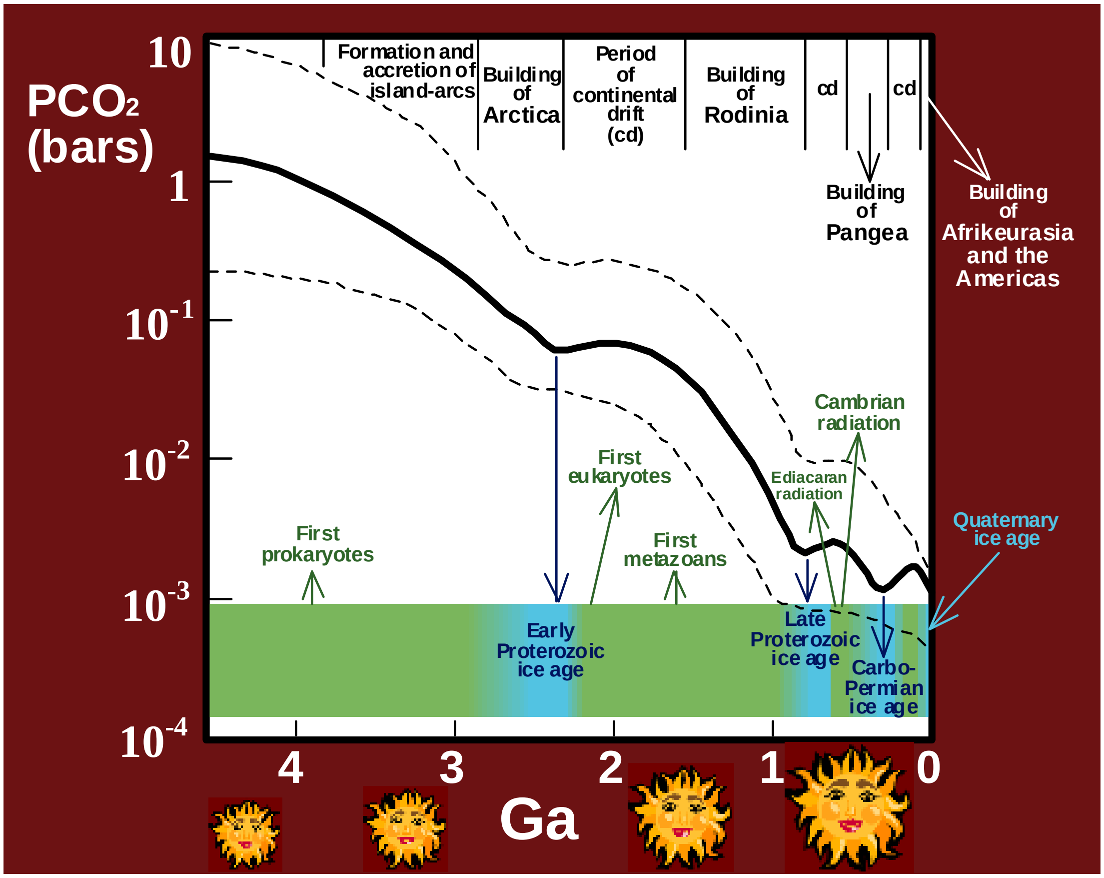

Figure 1: Main events of plate tectonic, life and climate history in relation to solar luminosity and the PCO_2 curve of Kasting (1993).

The "long-term" carbon cycle

Due to the capacity of water to absorb carbon dioxide, some of the original atmospheric carbon was removed when the ocean formed, nearly four billion years ago. In the first 500 to 600 million years of Earth's history, the accretional heat was maintaining water in its gaseous state, but as accretion rates subsided, the atmosphere became cool enough for water vapor to precipitate massively and form the ocean. Because interactions with an overlying body of standing water are necessary for the formation of continental crust, this primitive ocean was at first covering the entire planet, with no intervening continents. Moreover, because all the sodium of the modern ocean was provided by the erosion of continental crust, whereas most of its chlorine must have precipitated from the early atmosphere along with water, this primitive ocean must have been characterized by acidic freshwater.

The geological record suggests that organic life started almost as soon as the ocean was created, as organic tissues are found in the oldest sedimentary rocks, which are dated at 3.8 Ga (1 Ga=1 billion years old) (Condie and Sloan, 1998). A prerequisite for the formation of the first sedimentary rocks, and hence for the possibility of fossilizing evidence of life, was the formation of the first micro-continents (island arcs), which must have been no larger than the modern Japanese islands. It is possible that single-celled life may have appeared even sooner than these small 3.8 Ga continents. According to isotopic evidence, life would have started around ~3.9 Ga (Rosing, 1999). The theory that life may have started in the setting of submarine hydrothermal vents (Corliss et al., 1981) is therefore more plausible than the Darwinian theory, according to which life would have started in a “warm little pond”.

Evidence for photosynthetic life is only found by 3.5 Ga (Schopf and Packer, 1987; Schopf, 1993), but the incorporation of carbon to form organic tissues started with the most primitive forms of heterotrophic life. Therefore, a new sink for atmospheric carbon was created as soon as life started to develop. When the first continents emerged from the sea and started to provide calcium and magnesium to the ocean from the erosion of continental crust, microbial life facilitated the association of these cations with carbonate anions to form carbonate rocks (limestone and dolostone), which provide the greatest long-term sink for carbon dioxide. Indeed, most of the original atmospheric carbon is not found in fossil fuels, but rather in carbonate rocks, which are much more abundant in the Earth’s crust.

Although much carbon is transferred from the atmosphere to organic tissues through photosynthesis, most of it eventually makes it back to the atmosphere through respiration and decay. In the case of carbonate rocks, the main way to send the carbon back to the atmosphere is through volcanism at subduction zones. Hence, when the Earth’s plate tectonics is functioning properly, there is more-or less a balance between the amount of carbon that gets locked into the formation of carbonate minerals and the amount that gets recycled back to the atmosphere via volcanism at subduction zones. However, plate tectonics do not always function properly. Because of its low density, continental crust cannot be subducted, and continental masses are therefore bound to undergo occasional collisions, which work at impeding subduction, thereby lowering the amount of carbon released from the partial melting of carbonaceous rocks. On the other hand, continental collisions expose new crustal material to weathering, which increases the input of calcium and magnesium into the ocean, and which therefore promotes the entrapment of carbon within carbonate rocks. As a direct result, the Earth’s atmosphere experiences global cooling when plate tectonics are dominated by continental collisions and “supercontinental” accretions, and global warming when they are dominated by smooth subduction and continental drift.

The four main ice ages of Earth’s history

One very common misconception regarding ice ages and greenhouse ages is that they are controlled by orbital forcing. In fact, the Croll-Milankovitch cycles of eccentricity, obliquity and precession are second order cycles overprinted over much longer climatic cycles, which are controlled by plate tectonics. The Earth has experienced four periods dominated by pervasive glacial conditions for tens of millions of years, separated by extended periods of greenhouse conditions (Pagé, 1999) (Figure 1). The first major ice age occurred roughly between 2.7 and 2.3 Ga (Late Archean to Early Proterozoic), during the formation of Arctica, the first “supercontinent” (Figure 1). It is during the subsequent greenhouse age that eukaryotic life and eventually multicellular life developed under more clement climatic conditions (Figure 1).

The second ice age occurred during the breakup of Rodinia (second supercontinent), between 800 and 600 Ma (1 Ma=1 million years) (Late Proterozoic) (Hoffman, 1989). Because the Sun had substantially augmented its luminosity by that time, much more carbon dioxide had to be removed from the atmosphere for this second ice age to occur than for the previous (Figure 1). The ice age therefore only began during the post-orogenic rebound, in early stages of the breakup, when much crustal erosion was still occurring, whereas subduction rates were still low. During this ice age, which is often referred to as the “Cryogenic Era”, glacial advances are interpreted to have been at times global (“Snowball Earth” conditions), as climatic degradation exceeded the threshold to runaway albedo conditions that would allow the entire planet to be covered by ice (Hoffman et al., 1998). In the context of a Snowball Earth, the “carbonate factory” that forces carbon into the crust shuts down completely, allowing carbon dioxide levels to build up in the atmosphere from limited but continuing volcanic inputs. Because the ice-albedo feedback is hard to reverse, an excessive amount of carbon dioxide had to accumulate in the atmosphere to allow glacial retreat, which would be therefore followed by extreme greenhouse conditions (Hoffman et al., 1998). Gradual cooling towards the next glacial advance would occur as the carbonate factory resumed its business. In late stages of the breakup of Rodinia, plate tectonics became dominated by continental drift again, and the Earth returned to long lasting, warm greenhouse conditions.

The second ice age had caused stagnancy in the evolution of multicellular life, but the return to greenhouse conditions near 600 Ma allowed the radiation of the Ediacaran fauna, which was characterized by sophisticated marine organisms that lacked hard parts and that are therefore poorly preserved in the geological record (Figure 1). The sudden radiation of several classes of organisms with hard parts during the Cambrian (first period of the Paleozoic Era), starting at ~545 Ma, is thought to be related to the development of skillful predators in the warm oceans of this greenhouse period.

Already by the end of the Cambrian (500 Ma), plate tectonics became once again dominated by continental collisions, and gradual cooling occurred during the assemblage of Pangea (third supercontinent), which culminated at the end of the Paleozoic with the worst post-Precambrian extinction recorded in the history of life (Erwin, 1993) (Figure 1). This third major ice age was enhanced during the Carboniferous by the long-term storage of immense amounts of atmospheric carbon in large peat bogs that were cyclically buried and preserved under marine sediments as sea-levels fluctuated along with the Croll-Milankovitch cycles. Most of the coal used for industry was formed by the maturation of these Carboniferous peat layers during their deep burial. This efficient long-term sink of atmospheric carbon dioxide that was provided by the cyclic burial of Carboniferous peat increased the gravity of global cooling and contributed to the near-extinction of all life on Earth. This was also the only time in Earth’s history when carbon dioxide levels in our atmosphere were lower than they have been on average over the last two million years (Berner, 1990, 1991, 1992) (Figure 2).

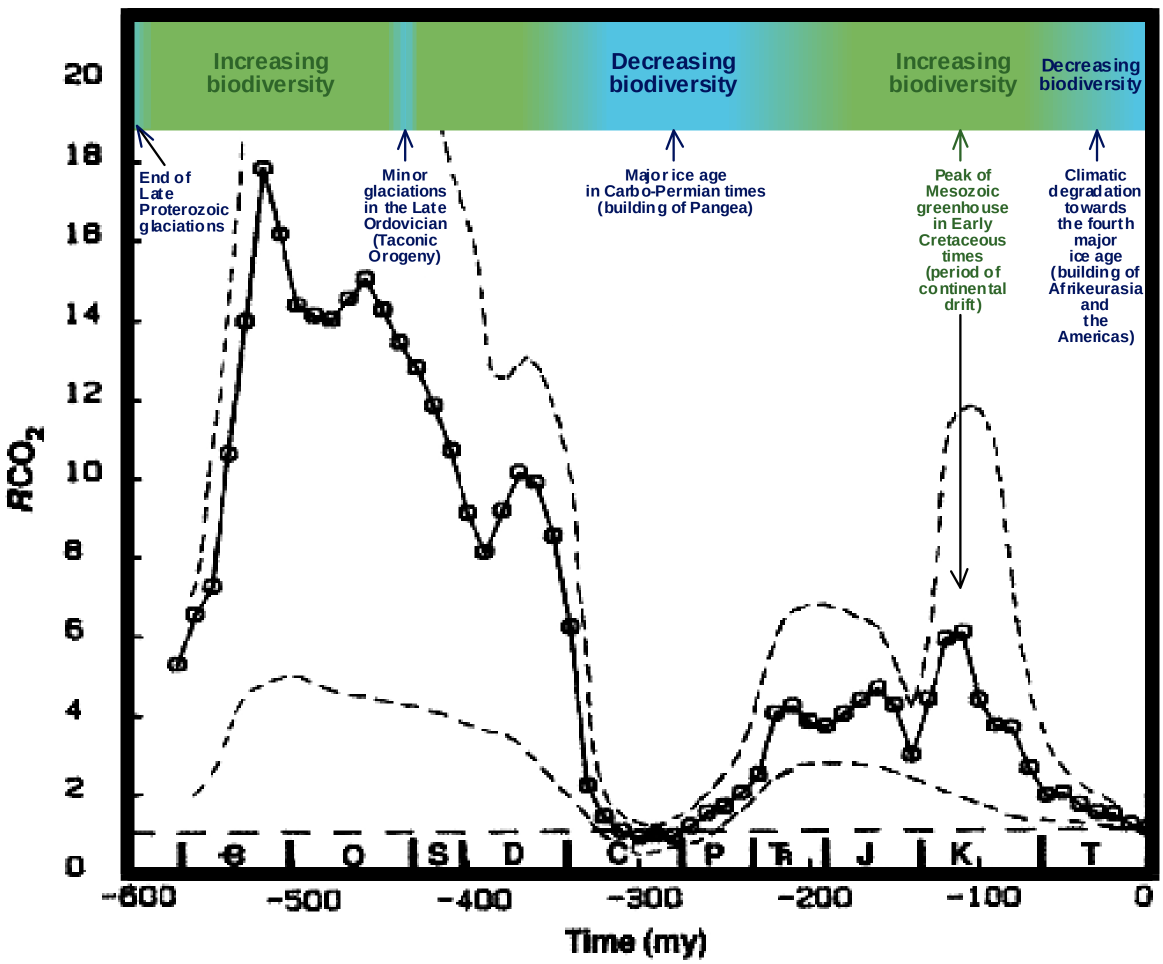

Figure 2: Main events of plate tectonic and climate history in relation to the RCO_2 curve of Berner (1990) for the Phanerozoic.

The breakup of Pangea during the Mesozoic allowed the Earth's climate to return to greenhouse conditions as plate tectonics became again dominated by continental drift, which resulted in the radiation of new life forms dominated by large reptiles. The peak of this warm greenhouse age occurred during the Cretaceous (Figure 2), which was also the time when biodiversity was perhaps greatest in all of Earth's history. The constant rain of microplanktonic corpses in the Cretaceous oceans resulted in the formation of thick deposits of chalk (composed of the microscopic calcareous tests of these organisms), from which this period gets its name ("kreta" is Greek for "chalk"), except at the very peak of this greenhouse period, when latitudinal differences in temperature became too small for thermohaline circulation to occur in the ocean. Today, it is because of thermohaline circulation that modern ocean floors are oxygenated. The fact that surface waters are normally warmer than deep waters does not allow thermal convection to occur in the oceans. Overturning of well oxygenated surface waters into the deep seafloor can therefore only occur after the former have traveled in lower latitude long enough for their salinity to be substantially increased by higher evaporation rates. Upon their return to higher latitudes, which is forced by the Coriolis effect paired with the density increase that results from increasing salinity, the hypersaline surface waters will sink to the seafloor as lowering temperatures further increase their density. In the middle part of the

Cretaceous, evidence that thermohaline circulation had stopped came in the form of “black shales”, which formed as the constant rain of microplanktonic corpses settled on an anoxic seafloor that did not allow organic matter to properly decay. This allowed acidic conditions to develop on the seafloor, which did not favor the preservation of calcareous tests. Cretaceous black shales form the most important source rocks in the World’s greatest oil reservoir (the Persian Gulf, the North Sea, the Gulf of Mexico, the Rockies’ foreland, etc.).

The preservation of organic matter in either chalk or black shale on the Cretaceous seafloor provided an important new sink for atmospheric carbon dioxide, which eventually caused the warming trend to inverse towards a new cooling trend (Figure 2). This warming trend had been largely caused by abnormally high rates of mid-oceanic ridge spreading and plate subduction in Cretaceous times (de Boer et al., 1988; Condie and Sloan, 1998). These high rates were temporarily caused by the runaway release of heat that had accumulated in the Earth’s interior while Pangea was still assembled. Supercontinental assemblages obstruct plate tectonic processes, which provide the main mechanism to release heat from the Earth’s interior. When the plate tectonic “machine” returned to a period of unobstructed continental drift, the accumulated heat was released through unusually high rates of hot spot, mid-oceanic ridge and island-arc volcanism, from which carbon dioxide was also released at an unusually high rate. As volcanic activity returned to more normal rates, rapid sinking rates of carbon dioxide in Cretaceous black shales and chalks eventually outdid carbon dioxide inputs from volcanism and the climate began to cool, starting in the middle of the Cretaceous (Figure 2).

The post-Early Cretaceous cooling trend has been perpetuating during the Cenozoic (the last 65 million years) as continents began to collide again, starting with the collision of India and Eurasia, and the collision of Africa and Eurasia. The separation of Antarctica and Australia around 35 Ma isolated the former on the south pole, and a circum-Antarctic oceanic current then developed and prevented waters from low latitudes to maintain temperate condition on this new continent, which has been developing an ice sheet ever since (Condie and Sloan, 1998). The presence of an Antarctic ice sheet greatly increased planetary albedo, thus providing a positive feedback on the cooling trend, pairing up with the ongoing orogenies. The climate eventually degraded enough for Greenland to start developing an ice sheet about seven million years ago. The collision of South and North America at 3 Ma gave the final blow for the onset of a fully developed ice age, partly because the formation of Central America created a major obstruction to global oceanic circulation, which usually works at distributing heat from the low to the middle and high latitudes (Pagé, 1999). Shortly after, ice sheets started to develop in mid-latitudes, intermittently covering most of North America and Europe during cold eccentricity cycles (glacial stages), and temporarily disappearing from these areas during warm eccentricity cycles (interglacial stages). This fourth major ice age has been going on for about 35 million years, and probably still has a long way to go, as plate tectonics are still dominated by continental convergence, and will still be for at least several tens of millions of years.

On a shorter time frame, we are now nearing the end of the Holocene interglacial stage, which peaked about five thousand years ago when the eccentricity, obliquity and precession cycles were all more-or-less at their warmest point (Figure 3). These three cycles are now heading towards the cold (Figure 3) and it is predicted that ice sheets will start forming again in mid-latitudes in about three thousand years (Pagé, 1999).

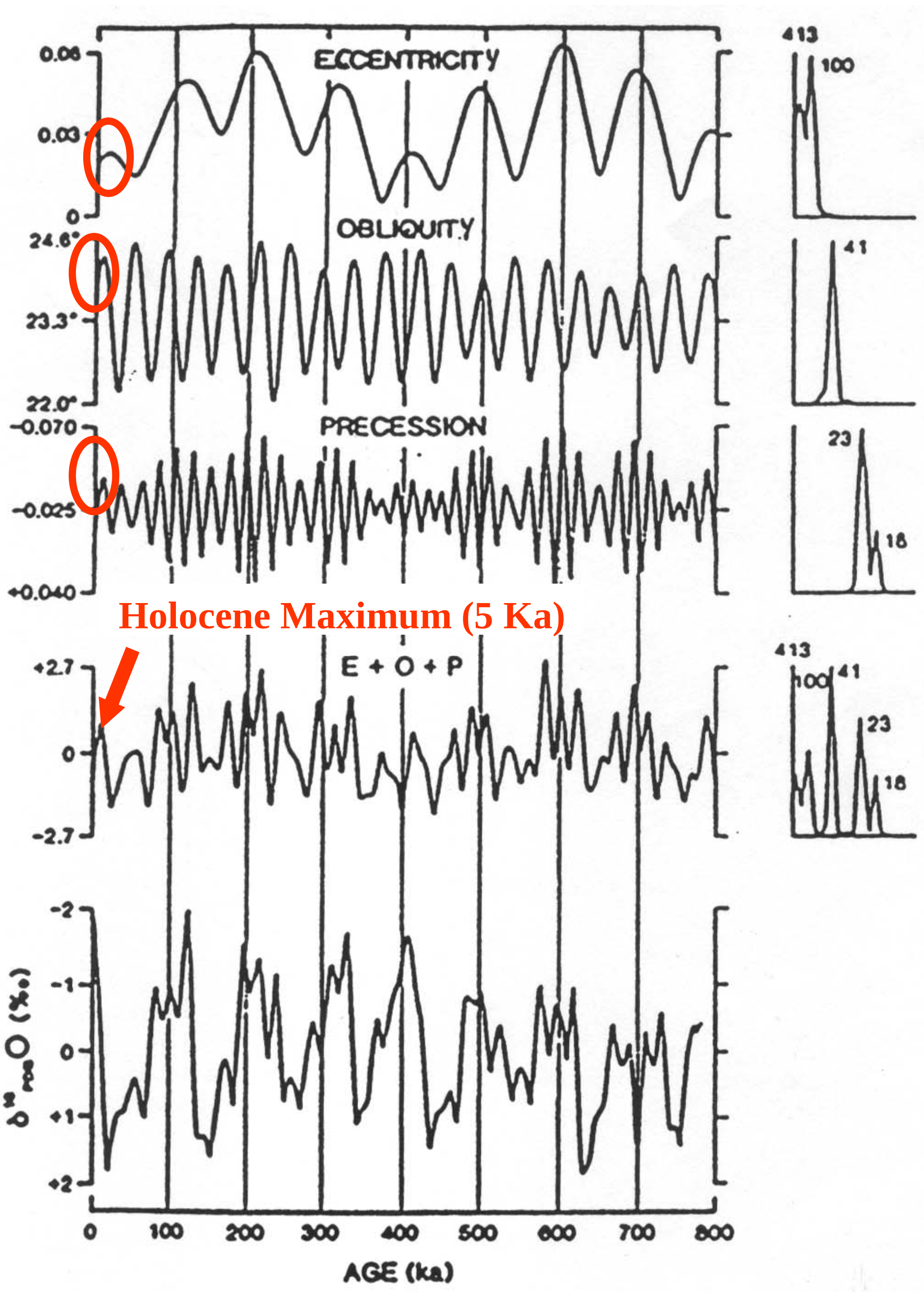

Figure 3: Milankovitch cycles in relation with oxygen isotopes in dated foraminifers (after Imbrie and Imbrie, 1979). Ka = thousand years.

Sediment cores extracted from the deep seafloor by the Ocean Drilling Program show evidence that ecosystems are under severe stress due to global cooling ever since Antarctica started to develop an ice sheet, 35 million years ago (Moran, 2006). This stress has only been increasing with the climatic degradation that has been perpetuating since. Even before humans appeared, the Cenozoic has seen many severe extinctions, especially during the present Quaternary Period (roughly, the last two million years). Excessive storage of atmospheric carbon dioxide in sedimentary rocks is the main reason for this stress, as carbon dioxide not only helps maintaining the climate warm enough for life to proliferate, but also provides the most essential nutrient for organisms that are at the very base of the food chain.

Discrepancies between the geological record and global warming models

Most predictions on the effects of global warming are fatalistic. It seems to be the general consensus that ecosystems will suffer, although geological history states the contrary. Models also predict an increase in desertification, although greenhouse ages, such as that of the Cretaceous, seem to be devoid of deserts, which are a feature of ice ages.

One recurrent theme in alarmist global warming models is the prediction that there will be an increase in tropical storms. Again, the geological record suggests otherwise. For one thing, it is wrong to believe that CO_2-induced global warming will result in a temperature increase for all regions of the globe. The absence of desertic conditions during greenhouse ages suggests that profound changes occur in sub-tropical latitudes due to CO_2-induced global warming, which may in fact result in substantial cooling for this specific latitudinal range. Due to the dynamics of the Hadley cells, moisture is currently conveyed from sub-tropical (10° to 30°) to equatorial latitudes (0° to 10°), which explains why the former is mainly characterized by deserts while the latter hosts rain forest. Due to this, sub-tropical latitudes are currently much warmer than equatorial latitudes due to the greater cloud cover in the latter region, which allows less solar radiation to reach the ground. Somehow (perhaps due to the establishment of a less steep vertical gradient in temperature, which would effectively change the dynamics of Hadley cells), moisture and heat become better distributed during greenhouse ages and sub-tropical deserts cease to exist. It is very likely that tropical storms would subside as well, as they are also the products of excessive heat in the dry, sub-tropical latitudes, whereas equatorial areas are devoid of them. The equatorial region is in effect a “shelter from the storm”, as suggested by a recent compilation by the National Oceanic and Atmospheric Administration (Figure 4).

In other words, although alarmist research on global warming pictures a greenhouse Earth as Dante’s Hell, the geological record rather presents it as a worldwide Garden of Eden, with no temperature extremes. Hence, because carbon dioxide stood out as the good guy throughout geological history, saving the day each time it shows up in large numbers, and because today’s low CO_2 budget is reminiscent of some of the worst pages in life’s history (Figure 2), reasonable doubt should be given to the alarmist scenarios that are currently being provided by climatic modelers.

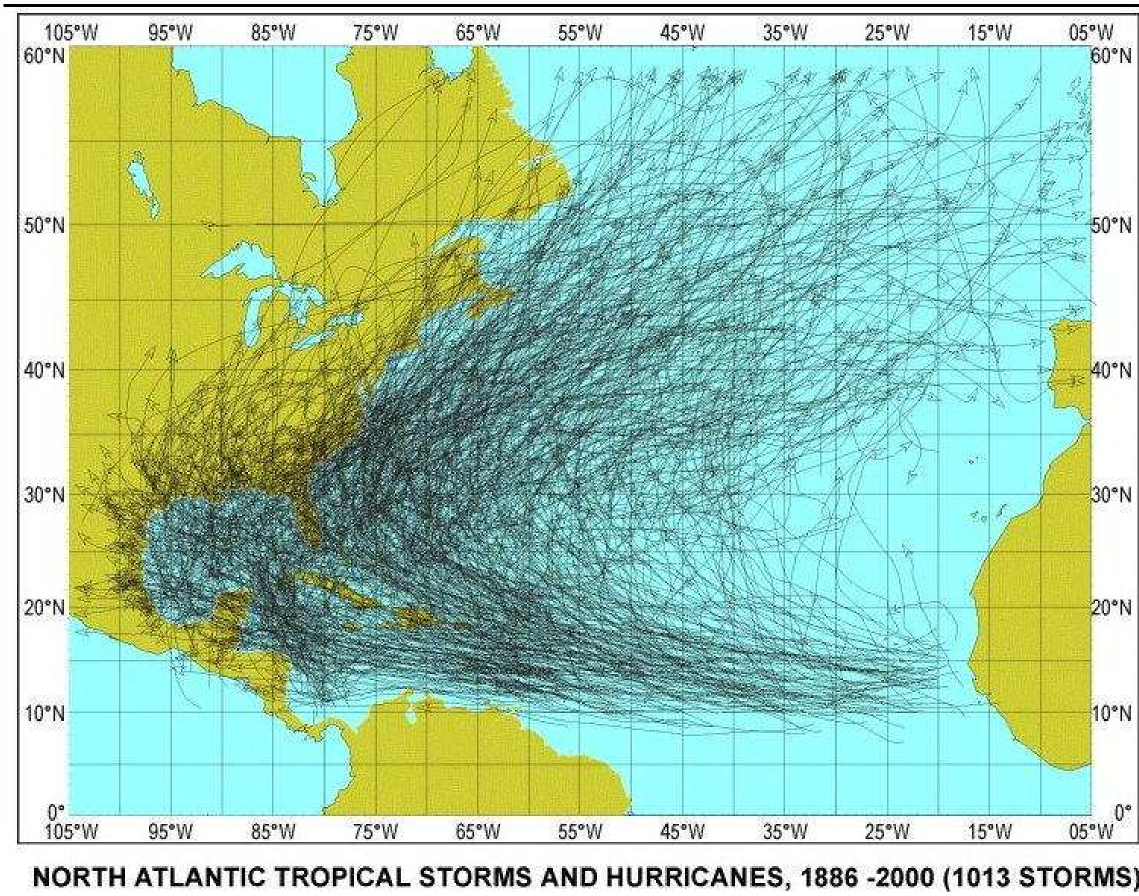

Figure 4: Compilation of tropical storm pathways between 1886-2000 by the National Oceanic and Atmospheric Administration (2005: http://www.magazine.noaa.gov/stories/mag184.htm).

Conclusion

Looking at the geological record, it becomes quite obvious that the overall global cooling that the Earth is experiencing is a more important concern for the health of ecosystems than the temporary trend of global warming that we are presently observing. Ironically, the only way to prevent the next glacial advance, which would be far more catastrophic for humanity than the so-called threat of global warming, is to keep sending back carbon dioxide to the atmosphere by releasing some of its excessive storage in the crust. Unfortunately, the release of carbon from carbonate rocks is energy consuming, but there very well might be enough accessible fossil fuels in the upper crust to give us the means to avoid suffering the next glacial advance. In other words, there might come a time when humanity will try to find ways to burn more fossil fuels in order to save the day. By then, the 1997 Kyoto Protocol might be seen as one of history's greatest parody.

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