Earth's Climate: Impacts on Habitat and Humans

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Putting Our Emergent House in Order

Nothing in the world lasts
Save eternal change.

Honorat de Bueil, seigneur de Racan (1589–1670),
"The Coming of Spring"

Dry winds blow across drought-ridden, rain-parched farms in Australia, followed by record flooding. Heavy rains inundate low-lying deltas in Asia and on the Pacific northwest coast of North America, flooding homes and making water unfit to drink. Death comes to pastoralists and farmers on the shrinking acreage of arable land in Africa as too little rain feeds too few crops. Intense hurricanes batter southern Atlantic coastal regions. The world looks on as Africa suffers escalating destruction; rising prices and shortages of food and basic goods, along with joblessness and stagnant wages, trigger protests and the destabilization of political regimes in Africa and the Middle East. Riots bring London to its knees. A global recession cripples the world as government debt soars in Europe and America. People die. At global summits on climate change, politicians refuse to sign agreements that would have them reduce their countries' emissions of the greenhouse gases blamed for causing global warming, or they renege on their previous emission-reduction commitments. Media reports swing between predictions of climate catastrophe and such derisive statements as "If we can't predict the weather next week, how can we predict climate next year?" A perplexed public is left not knowing whom to believe.

Most of us have unanswered questions about the real state of Earth's climate and its impact on local and global economies. This lack of understanding makes us feel helpless and uncertain about what we need to do and where we fit in this changing world. Assembling

answers to some of those questions will help us look at the issue more clearly, without feelings of panic or hopelessness.

Is climate change a natural phenomenon on Earth?

Yes, it is. The Earth is 4.5 billion years old, and before the first signs of life appeared, the land and ocean formations on Earth looked vastly different from what we see today. Even the continents situated so solidly beneath our feet were shaped and positioned differently. There was little or no oxygen in Earth's atmosphere then, hence no ozone and no protection from solar radiation. Initially, Earth's atmosphere contained hydrogen and helium. Later, as the planet cooled, it sent gases, including carbon dioxide, water vapor, and possibly methane into the atmosphere. Single-celled microbes released oxygen, a by-product of photosynthesis, which gradually accumulated in the oceans and atmosphere.

Less than a billion years ago, nearly all the surface water on Earth froze, and most of the planet was covered in ice, creating what is known as "Snowball Earth." Over millions of years, large volcanic eruptions emitted enough heat and carbon dioxide into the atmosphere to create a greenhouse warming effect that melted the ice and brought an end to the "snowball" state. These dramatic fluctuations in climate had a devastating effect on the life forms evolving in the oceans, but about 500 million years ago (for a timescale of the geological history of Earth see Figure 1.1), the big bang of animal evolution took place. This saw the origin of all the major phyla (groups of organisms). By about 450 million years ago, plants had invaded the land, their vegetation covering the previously barren landscape. And 50 million years ago, Earth's climate was sufficiently warm for the Arctic to experience a Mediterranean climate with temperatures as high as 24°C.[1] And the changes continue.

Does climate change cause species extinctions?

History suggests it does. Five major extinction events have occurred on Earth in the past 450 million years, and scientists believe that at least one of them – which took place at the end of the Cretaceous period 65 million years ago – may have been related to sudden and catastrophic climatic changes caused by bolide impacts (i.e., meteorites, comets, or asteroids hitting Earth) or other geological events, including large volcanic eruptions that spewed forth huge lava flows.[2]

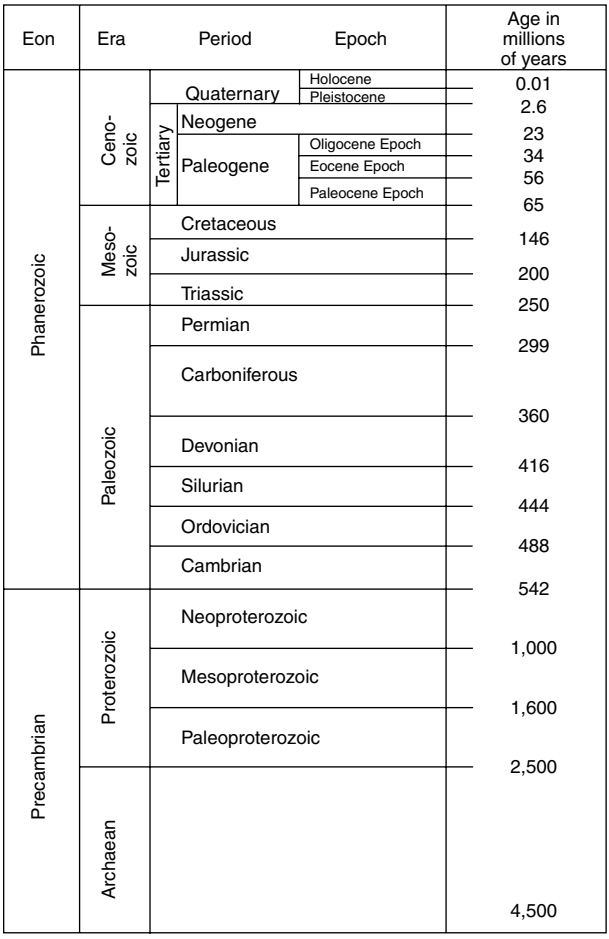

Figure 1.1. Geologic timescale.

The high-energy radiation, heat, and pressure created when bolides hit kill everything at the point of impact. Everything in the splash zone of vaporized and molten rock and solid debris is also killed. Surface waters of lakes and seas become acidified. Smoke and dust clouds block the sun's rays and cause a drastic drop in temperature. Bolide impacts are also thought to trigger large-scale volcanic eruptions that may, in the long term, have greater climatic influence.

It's possible the Chicxulub comet, which landed in the Yucatan Peninsula around 65 million years ago, caused the Cretaceous extinction, or it might have been due to large volcanic eruptions that churned

forth huge lava flows in India.[3] Whatever the cause, the extinction event at the end of the Cretaceous period was the second largest in Earth's history. At least 85 percent of all species disappeared, including the dinosaurs. Some scientists suggest that heat stress associated with bolide impacts caused new species to emerge. This may be true, but many of the groups used as typical examples, including mammals and flowering plants, existed before the catastrophe, although they were far less numerous, less diverse, and much less widespread. (For example, the mother of all mammals, affectionately named "Jurassic Mother," a little 15-gram shrewlike animal that clambered about in the trees in search of insects to eat, first appeared about 160 million years ago.[4]) These groups had been in a state of "dynamic stasis," which means their form and distribution was relatively stable and resistant to change.[5] They were liberated from this state when the dominant cycads, ferns, and reptiles were exterminated in the Cretaceous catastrophe. The number and range of marsupials (i.e., the "pouched" mammals like opossums, wombats, and kangaroos) expanded first, but another climate catastrophe at the end of the Eocene epoch, about 34 million years later, provided an opening for the "Jurassic Mother" and all placental animals (i.e., animals that carry their young inside the mother's womb for long gestation periods and bear live young, like dogs, cats, horses, and humans) to diversify.

French naturalist Baron Georges Cuvier (1769–1832) did not accept the idea of evolution, believing instead that all species were created at the same time. However, he recognized that catastrophes could result in species' subsequent extinction. According to Cuvier, all organisms were so perfectly adapted to their conditions of life that any destabilization of their environment was detrimental. This made evolution impossible. Thus, when a climate catastrophe occurred, organisms not suited to the devastated or changed environment could not change and went extinct. Those that did possess appropriate characteristics then moved into the vacated territory and flourished.

In many ways, Cuvier was right: Natural catastrophes did cause mass extinctions. They resulted in the demise of dominant species that were well-suited to the previously stable environment. They also opened up new environments for the survivors; however, those survivors needed a combination of luck, physiological and behavioral adaptability, and intelligence in order to adjust to the changed environment, diversify, and become the new dominant species.

When did humans appear on the scene, and what did that scene look like?

It took quite a while for humans to appear. Our early ancestors were some of those lucky, adaptable survivors, but it was not until between about three and four million years ago that the bipedal apes – hominins like *Paranthropus* (an early, now extinct, bipedal hominin) and *Australopithecus* (an early bipedal hominin believed to be related to humans) – appeared on the scene in Africa.[6]

Until the mid-1980s, anthropologists believed that one of those hominins, *Homo erectus*, was our direct ancestor. *Homo erectus* appeared in Africa about 1.9 million years ago and left Africa for Europe and Asia around 1 million years ago. Later, some anthropologists thought that *Homo erectus* split into two species: *Homo erectus* and *Homo ergaster.* According to this theory, *Homo erectus* went east to Asia and later became extinct, whereas *Homo ergaster* began life along the shores of Lake Turkana, Kenya, some 1.9 million years ago and continued on in Africa to become our direct ancestor. Although *Homo erectus* disappeared relatively early in the west, the species persisted in China until about 230,000 years ago and survived in Java until around 50,000 years ago (for a timeline showing key early *Homo* species events see Figure 1.2).

But, surprisingly, the first evidence of ancestors that combined the traits of both *Homo erectus* and *Homo ergaster* with modern human traits has been found not in Africa, but in Spain and possibly Italy. *Homo antecessor,* potentially the common ancestor of both Neanderthals and ourselves, appeared about 800,000 to 900,000 years ago in a Mediterranean forest environment among oak and cypress trees, mammals, and birds very similar to those alive today. Our cousins, the Neanderthals, separated from our own evolutionary lineage at least 500,000 years ago. This heavy-set, big-brained, human-looking species migrated into Europe and Asia long before *Homo sapiens.* They roamed Europe and western Asia, according to some, alone and unchallenged until humans arrived.

It was not until about 200,000 years ago that *Homo sapiens,* in the form we think of as human, appeared in Africa. About 120,000 years ago, when warm, wet conditions encouraged the African rainforests and mangrove swamps to expand and dry forests and savanna to shrink, the vegetation and fauna from northeast Africa extended eastward into the Levant, motivating *Homo sapiens* to move eastward out of Africa, following the vegetation and fauna into what is now Israel. Because *Homo sapiens* were simply following an extension of

Period	Event	Age in thousands of years
Quaternary	*Homo sapiens* reach New Zealand	0.8
	Homo sapiens reach Hawaii & Easter Island	1.1
	H. sapiens reach Pacific Islands, *New Caledonia & Samoa*	3
	Aboriginal peoples inhabit Canada's Arctic	6
	Short cold event	8.2
	Holocene warm interval & first agriculture begin, megafauna extinction in N. America	10
	Homo floresiensis disappears	17
	Younger Dryas cold spell	12.7–11.7
	H. sapiens appear in the Americas	>20–10
	Coldest time of last ice age	21
	Neanderthals disappear	24.5
	H. sapiens in NE Russia	32–18
	H. sapiens in Tasmania	35
	H. sapiens appear in Europe, New Guinea	~40
	H. sapiens appear in Australia	~45
	H. erectus disappears in Java, cultural renaissance in Europe	after 50
	Behaviourally modern *H. sapiens* appear in China	~67–30
	Neanderthals in W. Russia until	~73–36
	H. floresiensis appears on Flores Island	74–38
	H. sapiens migrate out of Africa	~119
	Beginning of last glacial cycle	135
	Modern humans appear in Africa	~200
	Last *Homo erectus* in China	230
	Neanderthals separate from *Homo* lineage; *H. erectus* in Japan	by 500
	H. erectus? on Flores Island	840
	Wooden javelins in Germany	900
	H. erectus dispersal out of Africa	Prior to 1000
	Early stone tools	2300
		2600

Figure 1.2. Quaternary timeline.
Source: Adapted from Hetherington, R., and Reid, R.G.B. (2010). *The Climate Connection: Climate Change and Modern Human Evolution. Cambridge*: Cambridge University Press, p. 6.

their African habitat, these early human explorers did not have to substantially change their behavior to adjust to their new home.

Between 60,000 and 30,000 years ago the world's climate became very changeable. Extensive ice sheets stretched across the northern hemisphere, and a polar desert likely covered much of central Eurasia. These barren northern landscapes probably discouraged modern humans from straying too far north. Instead, by about 45,000 years ago, when global average sea level had dropped 70 meters below what it is today, they migrated along the southeast Asian coast and into Australia. It was not until about 40,000 years ago that *Homo sapiens* moved into Europe, and soon after that the climate worsened, becoming cool, dry, and very unstable. Persistent ice sheets to the north and an expanding polar desert to the east confined *Homo sapiens* and Neanderthals to a shrinking habitat in Europe. Neanderthals had survived earlier glaciations and subsequent warm periods, but this one was different. *Homo sapiens* seemed to thrive in the highly variable conditions, but Neanderthals did not. By 28,000 years ago, the last Neanderthals disappeared from central Europe, although they remained in what is now Portugal until as late as 24,500 years ago, when the world was solidly in the depths of the last ice age. About 20,000 years ago, when ice sheets up to 2 kilometers thick extended across much of northern North America, *Homo sapiens* moved into the Americas.

Homo sapiens migrated out of Africa and around the world during the last glacial cycle, a time between 135,000 years ago and about 11,650 years ago, when the world went through a series of ice ages and warm intervals (see Figure 1.3). Temperatures in Antarctica during that period fluctuated between 4°C warmer (when the glaciers were in retreat) and 10°C colder than today (when the glaciers had spread to their widest extent). During the cold periods, massive continental ice sheets covered northern North America, Greenland, Europe, and northern Asia. Global average sea level fell by as much as 120 meters as huge quantities of fresh water were locked up in glaciers. The large underwater shelves that extend out from the edges of the continents emerged from the sea. These exposed continental shelves became available for early humans to inhabit and travel along as they migrated from place to place.[7] One of them, the Beringia Shelf, linked northeast Asia to North America when sea levels were lower. Some say this subcontinent provided a route for humans as they moved into the Americas during the last ice age.[8]

Yet despite the erratic climate and their lack of protection from cold, hunger, and wild animals, humans not only persisted but spread throughout the world. By the onset of the worst and most pervasive

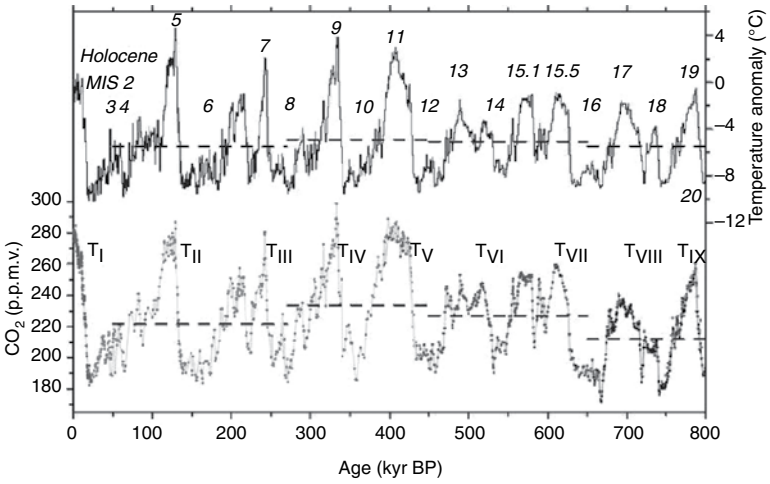

Figure 1.3. CO_2 records and temperature reconstruction of lower atmosphere over the last 800,000 years based on air trapped in ice cores from Antarctica. Temperature is expressed as an anomaly relative to present-day values. For example, during the depths of the last ice age, air temperatures over Antarctica were about 10°C colder than today. The data, described in Lüthi et al. (2008) and Petit et al. (1999), is derived from analysis of historical stable isotopes from the EPICA Dome C and Vostok ice cores.[9] Reprinted by permission from Macmillan Publishers Ltd. *Nature*

period of the last ice age (about 21,500 years ago) humans had colonized Asia and Australia, begun their migration to the Americas, and, as a result of the demise of the Neanderthals, become the sole *Homo* species in Europe. By 17,000 years ago, our last known *Homo* relative – *Homo floresiensis,* a three-foot-tall human that lived in Indonesia – went extinct.

Roughly 15,500 years ago, the climate began to warm rapidly as Earth cycled out of the last ice age. The enormous glaciers that soared kilometers in height over much of the northern hemisphere swiftly receded, leaving large glacial lakes in their wake. Global average sea level rose and the continental shelves sank beneath the sea. The homes and gathering sites of coastal humans living along the previously productive and relatively flat continental shelves were soon inundated by rising seas; people had to move inland, often to more hilly, mountainous, and forested terrain. Much of the marine food they had gathered and hunted was lost as their previous hunting and gathering grounds disappeared beneath the sea. As a result, food resources from the land likely became a more important part of their diet. An exception to