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Can History Help Us with Global Warming?

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It is prudent, both intellectually and practically, to accept that the atmosphere and oceans are indeed warming, as the evidence tells us, and that this trend will accelerate in the decades ahead. While we do not and cannot know just how much warming will occur, nor how fast, we can safely say that the rapidity of warming, now and in all likelihood over the next decades, has few precedents in the history of the Earth and none in the history of civilization. This is true regardless of which of the three versions of the future offered in this book one prefers.

No instrumental records exist for prior episodes of climate change. The proxy evidence used for the reconstruction of climate history—measurements of fossil pollen, foraminifera, tree rings, oxygen isotopes in air bubbles trapped in ancient ice, and other tools—can give a good but not precise idea of past temperature and precipitation patterns.

Earth's climate has never been static. For the past 2.7 million years, it has shown a pattern of alternating long ice ages and shorter interglacials, governed by cycles in the Earth's orbit around the sun. The last ice age was at its height around 20,000 years ago. Its end (circa 11,000 to 6,000 years ago) was probably crucial for human history as it coincided with the emergence of agriculture in multiple locations. After that bout of warming—generally much slower than what we have witnessed in the last hundred years but not without sudden lurches now and again—global climate changed only modestly and slowly until the industrial age.[1] Although our Paleolithic

ancestors did have to cope with rapid climate change from time to time, when they did so the Earth had fewer people (or hominids) than Chicago has today, and they were accustomed to migrating with their scant possessions as a matter of course. Their response to adverse climate change (as to much else) was to walk elsewhere. Since the emergence of agriculture, sedentarism, civilization, and the settlement of all habitable parts of the globe, the Paleolithic response has become more and more impractical. Thus, although there are analogues in Earth's history for the climate change now under way, there are none in human history. We have entered uncharted terrain.

Buffers, Resilience, and Nature's Shocks

As a species, we've enjoyed a run of luck in the Holocene, the geological period covering the last ten thousand years. Migration as a response to adversity has become progressively less viable, yet warming and cooling trends and attendant sea level fluctuations have remained small. Even the Little Ice Age, from approximately 1300 to 1850, amounted to an average cooling (in Europe, where the data are best) of just about 0.5°C (0.9°F). It made harvest failures more frequent in northern Europe and probably contributed to the demise of the tiny Greenland Norse settlement in the early fifteenth century. In lower latitudes, the Little Ice Age probably brought reduced rainfall and more frequent droughts—a much more disruptive experience than mild cooling or warming. But as nature's surprises go, the climate change of the Little Ice Age was modest.[2]

In the past, nature's shocks and stresses challenged all societies. In recent millennia, the most dangerous of these included epidemics, droughts, floods, earthquakes, and volcanic eruptions. Warming, cooling, and sea level changes were far down the list. Broadly speaking, these challenges came in two varieties: short, sharp shocks with durations of days, weeks, or a year or two; and long, slow stresses that played out over decades or centuries, and were often invisible to people at the time. In terms of demographic losses, epidemics were by far the most serious.[3]

Box 2-1 ranks the demographic seriousness of nature's shocks in very rough terms. The mortality figures, given only as an order of magnitude, represent the maximum, meaning 95 to 99 percent of such incidents would kill fewer people. So, for example, although there may have been a flood or even ten floods that killed more than 1 million people, this represents the worst that floods have ever done to humankind.

Approximate Maximum Mortality Levels from Nature's Shocks

Volcanic eruptions	10^4
Earthquakes	10^5
Floods	10^6
Droughts	10^7
Epidemics	10^8

The worst epidemics have killed 30 million to 100 million people, even if one considers the bubonic plague pandemic in fourteenth-century Eurasia (and possibly Africa) as a single event (a pandemic is an especially widespread epidemic, often global in scope). The most recent epidemic on such a scale, the influenza that raged from 1918 to 1919, killed perhaps 40 million (about 2 percent of the global population). The ongoing AIDS pandemic has so far killed 25 million to 30 million, about 0.5 percent of the current world population.[4] Such pandemics have been mercifully rare, but past epidemics that affected regions or single cities were not, and they routinely killed 5 to 10 percent or even more of the affected population.

Droughts, at their worst, have resulted in a few million deaths. The long history of drought is notably fuzzy, and whether or not deaths ought to be laid at drought's door is often unclear, especially for the deeper past. In the twentieth century, where the uncertainties are reduced, the deadliest droughts occurred in China from 1928 to 1931, in 1936, and in 1941, with 2 million to 5 million deaths on each occasion, generally because of starvation. The famous droughts in West Africa's Sahel region of 1967 to 1973 and again in the early 1980s each killed about 1 million people. In all probability some of the drought-induced Indian famines of the nineteenth century killed greater numbers, but the figures are in dispute.[5]

Floods, too, could kill thousands, even millions, although flood control and evacuation procedures have made a big difference in flood mortality. Since 1953 the annual average number of flood-caused deaths in India, the country most afflicted by floods, has been about 1,500. The worst flood in recent Chinese history, when the Yangtze surged in 1954, killed 30,000 people. Yangtze floods in 1931, perhaps the most costly ever, killed 1 million to 4 million, and those on the Hwang He (Yellow River) in 1887 resulted in perhaps 1 million to 2 million deaths. The great North Sea floods of December 1953 killed some 2,400 in the Netherlands, whereas earlier floods, in 1212, had killed 60,000. A 1342 megaflood in central Europe affected dozens of rivers,

caused half of all the soil erosion over German lands in the past millennium, and probably drowned hundreds of thousands of people.[6] In 1927 the worst flood in U.S. history—until those caused by Hurricane Katrina in 2005 killed 243 people along the lower Mississippi River.[7]

Of the many thousands of deadly earthquakes, only ten have killed more than 100,000 people. The worst occurred in China in 1566; perhaps 800,000 died. The recent tsunami of December 2004, created by an undersea earthquake, killed 284,000, and the 2005 earthquake in Pakistan killed about 79,000. The San Francisco earthquake of 1906, the worst in U.S. history, killed about 3,000.[8]

Of the countless volcanic eruptions, only six are likely to have killed more than 10,000 people. The worst case, the explosion of Mount Tambora, on the northern coast of Sumbawa island, Indonesia, in 1815, took perhaps 92,000 lives; Krakatoa, in 1882, cost 36,000. The famous eruption of Mount Vesuvius in 79 C.E. killed about 3,600, and the worst in U.S. history, that of Mount St. Helens, Washington, in 1980, killed 57.

With the exception of the richer parts of the world since 1919, every generation everywhere lived under the threat of devastatingly lethal epidemics, floods, droughts, and other kinds of natural risks.[9]

As a result, all societies had to build resilience to nature's shocks. By and large, they did not intentionally build resilience or resistance to nature's slow-acting stresses, such as desiccation (the gradual drying of climate) or soil salinization, because these progressed too slowly to cause alarm, and often too slowly even to be noticed from one generation to the next. But resistance and resilience to the easily observable short, sharp shocks were, always and everywhere, an important priority.

Resistance and resilience are not the same thing. Resistance to flood, for example, can take the form of the construction of seawalls and dikes, as the Dutch have done for seven hundred years to keep the North Sea at bay. Resilience to flood means the capacity to recover as quickly and easily as possible, which might take the form of leaving a river floodplain uninhabited and using it only for seasonal pasture, as was done along the Rhine until engineers straightened and narrowed its channel beginning in 1817.

Societies built resistance to nature's shocks as a conscious enterprise. In regions of the world prone to drought, they developed water-storage infrastructure such as cisterns. In flood-prone regions, they built levees. Cities developed quarantine routines to try to prevent epidemics. By the eighteenth century, China's Qing dynasty had constructed an elaborate system of state granaries intended to prevent famine from whatever cause. (The

Aztecs had done this on a smaller scale in the fifteenth century.) By the nineteenth century, richer societies undertook to control river floods with dikes, dams, and canalization, as on the Rhine, for example.[10] Since the 1880s public health services have made major efforts—by and large crowned by success—to prevent epidemics, by means of sanitation reforms and vaccination regimes. Otherwise there would not be 6.4 billion people today.

There have always been limits to the degree to which resistance can be built. Preventing volcanic eruptions remains impossible and stopping lava flows implausibly expensive. Flood control is feasible but only within limits; levees and dikes occasionally are overwhelmed, as occurred in the Mississippi basin in 1927 and 1993 and most recently in New Orleans in 2005. Moreover, as the Mississippi and New Orleans floods show, societal faith in the infrastructure of resistance can undermine resilience: the opportunity cost of leaving a floodplain unoccupied seems excessive if one trusts the levees and dikes.

Resilience, on the other hand, has to date proved to be in abundant supply: our species has survived countless shocks and now covers the globe as never before. In our earliest years, resilience consisted mainly of mobility—the ability to escape the worst of a natural shock through migration and to start afresh in a new landscape. Until recent decades, this remained an option for millions of pastoralists and the few remaining hunting and foraging populations. As recently as 1912 to 1915, when severe droughts affected the West African Sahel, millions of people adapted by migrating southward—a feasible response because in those days West Africa had about one-eighth the population it carries today, and there were no effective border control regimes to inhibit migration. For the great majority of our historical experience, mobility was the survival response to nature's shocks. Today it is severely restricted.

A second source of resilience in times past was simplicity combined with fertility. Societies with minimal infrastructure lost little except people when a natural disaster struck, and new people were easily created. Rebuilding a complex city in the aftermath of a flood or earthquake requires much more knowledge, investment, coordination, and cooperation than does rebuilding a patchwork of fields and villages. Most peasant societies prior to the twentieth century had a large number of unmarried young people who, in the wake of deadly catastrophe, would stampede into marriage and within a year sharply raise birth rates. This was not a conscious strategy, but a result of custom and economic preferences. Nonetheless, it provided resilience in the form of the ability to ramp up fertility quickly and jump-start demographic recovery.[11]

For many centuries societies have also consciously created more mechanisms to improve resilience. Storing food in state warehouses to cope with famine is a strategy intermittently practiced since ancient times and brought to a high level of reliability by the Qing dynasty in eighteenth-century China.[12] Transportation infrastructure, although built for other reasons, also provided resilience in that it allowed both faster evacuations from affected zones and quicker rescue and relief. Thus societies with extensive and dense road or canal networks, or both, eliminated famine by the end of the eighteenth century, while those lacking transportation infrastructure remained vulnerable.

Organized relief efforts also improved resilience in modern history. The practice of maintaining contingency funds against disasters is probably nearly as old as money and treasuries. The practice by governments of providing funds for disaster victims in other countries dates back at least to a great Jamaican hurricane of 1783 and a Venezuelan earthquake of 1812. The first standing international body devoted to disaster relief probably was the Red Cross, founded in 1863, though until the late 1940s it concerned itself almost entirely with victims of war, rather than nature's shocks.[13] The total effect of such efforts and organizations upon societal resilience has to date been modest, but they have eased the suffering of millions.

In the last two or three centuries, as societies have grown more complex and as mobility has become less feasible as a societal response, resistance and resilience have come to take more technological and bureaucratic forms, such as granaries, seawalls, and international relief organizations. Since 1950 or so, the ability to evacuate millions and to bring large quantities of food and other supplies, quickly and over great distances, has improved immensely. As a result, the causes of modern famines have typically been war and totalitarian politics, rather than environmental factors.[14] Ironically, the logistical capacity to do such things was in large part developed to meet the military requirements of global war, especially in World War II.

As a consequence of this technological and organizational progress, disease, droughts, floods, and earthquakes that a century or more ago might have killed millions more recently would only kill thousands. This extraordinary ability to mitigate disaster has hinged on the relative stability of international politics since 1945, which has provided an opportunity for what we might call "regimes of resilience" to develop. However, the rapid population growth in these same decades imperils resilience by making it harder to maintain uninhabited or sparsely populated buffer zones, wetlands, mangrove forests, floodplains, and so forth. Resilience in the face of drought

or similar shocks can be harder to maintain in more crowded circumstances, as can resistance to infectious disease.

In the past, vulnerability to shock had several components. First and most obvious, the intensity and duration of natural shocks often made all the difference between survival and catastrophe. Societies that could withstand one drought a year with only hunger could not withstand two without starvation. Second, some societies had, by design or accident, less in the way of buffers or resilience than others. For example, a society that had few or no domestic animals could not survive a harvest failure as reliably as could a society that could eat its animals one by one if circumstances required it. Societies that had poor transportation infrastructure could not import food as readily or cheaply as could those with good roads, canals, or, eventually, railroads. Nor could the isolated receive any available government or charitable assistance as easily. Societies that used nearly every available acre as farmland and preserved very little in the way of woodlands or wetlands, such as that of early-twentieth-century rural China, proved more vulnerable to floods than did those that (by accident or design) kept land in reserve, because floodwaters sitting on unpopulated or uncultivated land were merely an inconvenience, not a catastrophe. Societies without active and able public health systems suffered more from epidemics than did those that had such systems.

Less obvious, perhaps, were differences in levels of ecological ignorance. Populations that have lived in one environment for several generations gradually acquire, and usually take pains to transmit, knowledge of how to survive and prosper within the limits of their environment. They also gradually form a sense of the boundary conditions to be expected and know from oral tradition that they must be prepared for adversities—locust invasions, prolonged drought, and so forth—beyond their own personal experience. Populations present for dozens of generations normally had exquisitely fine-tuned ecological knowledge and knew where to find edible plants to see them through famine, where to find underground water when there was none on the land's surface, and so forth. Such knowledge contributed materially to resilience.

Conversely, in many instances, especially in the last two centuries, the prevalence of cheap transportation and more long-distance migration has meant that many populations found themselves operating experimentally in new environments. This was true of the British and Irish settlers in Australia after 1788, who inevitably misunderstood antipodean ecology and often paid a price for it.[15] It was true of the American farmers on the southern

plains, almost all of whom came from more humid climes, who during the 1930s drought naturally presumed that the wetter years of 1915 to 1930 were normal. They were ignorant of the cyclic drought patterns of the plains; through their farming practices they inadvertently turned the southern plains into the Dust Bowl in a routine drought. Ecological ignorance also lay behind the failures of the Soviet Virgin Lands scheme of the 1950s, in which Premier Nikita Khrushchev ordered an area of dry Siberian and Kazakh steppe land the size of California to be planted in wheat, only to see the region experience, within a few years, disastrous drought, dust storms, and harvest failure.

Societal and Political Reverberations

Even though natural shocks regularly took a significant demographic toll, it is worth emphasizing that the great majority of floods, drought, epidemics, and so on had only local or regional effects and took the lives of small numbers of people. In the distant past, because the human population was small, the numbers of victims were small. It has remained true over the past fifty years partly because of luck (nothing really bad has come up since the influenza pandemic of 1918 to 1919) and partly because public health systems, disaster management systems, and so forth have grown remarkably effective. The worst historical era for demographic losses from natural shocks came between 1300 and 1920.

Interestingly, heightened mortality was not the only source of demographic decline connected to natural shocks. When young people's expectations for the future were lowered and their faith shaken, they tended to postpone marriage, either of their own will or because their elders required it. Moreover, married people, in such dark times, found ways to restrict their fertility. Consequently, for the duration of most disasters, and in the wake of those that were especially disheartening, not only did more people than usual die, but fewer than usual were born. Wars and severe economic depressions also produced this effect. Its magnitude varied tremendously, with the degree of discouragement and the availability of knowledge and means for contraception.

Normally, if disaster was followed by good fortunes, exuberant fertility made up for the losses within a few years. In some cases, however, reproductive slowdowns and strikes lasted decades. This appears to have been the case with the native populations of the Americas during and after the relentless epidemics of the sixteenth and seventeenth centuries.

The economic effects of natural shocks, unlike the demographic ones, have tended to grow and grow. But that is mainly for cheerful reasons: the world economy is now so large that there is much more at risk. Global GNP grew fifteenfold in the twentieth century, and more than fourfold in per capita terms.[16] The direct effects of damage to property depended on where disasters occurred. None were worse, in monetary terms, than the Kobe earthquake of 1995, whose costs may have topped $200 billion, and 2005's Hurricane Katrina, whose costs are put variously between $25 billion and $100 billion. The Indian Ocean tsunami of 2004 led to about $10 billion in direct economic losses.

The Kobe earthquake mangled a densely populated and built-up part of Japan, the country's industrial heartland. It killed 4,571 people and knocked down more than 67,000 buildings. The monetary costs came to about 2.5 percent of Japan's 1995 GNP, and led to the failure of financial institutions such as Barings Bank that were deeply invested in the Japanese property market (Japanese property often carried no earthquake insurance).[17]

Whereas storms and earthquakes often had locally devastating economic effects, droughts—at least as measured by government efforts at compensation—by and large did not. In the United States, estimated annual federal expenditures to mitigate the consequences of droughts averaged half a billion dollars between 1953 and 1988. Federal costs rose from the 1950s to the 1980s, but even the worst case, the drought years from 1987 to 1989 on the Plains, did not much exceed $2 billion a year. During the Dust Bowl decade of the 1930s the government provided far less.[18]

Discrete natural shocks such as hurricanes or floods proved more costly. In the 1950s the American total economic losses came to roughly $4 billion per annum on average. By 2003 that figure had swollen to $65 billion, and in 2004 to $145 billion, according to Munich Re, the world's biggest reinsurance firm. About two-thirds of the costs incurred came from floods and storms. The mass migration into flood-prone regions since 1930 and the consequent creation of housing stock and infrastructure chiefly account for the tremendous rise in the cost of floods and storms. Florida's Broward County, a routine landfall for hurricanes, had 20,000 people in 1930; by 2000 the population was 1.6 million.[19]

Although the costs from nature's shocks rose rapidly—and the shocks could have devastating local effects for a decade or more—none in modern history, not even the 1918-to-1919 influenza, had durable economic consequences that changed the basic fortunes of nations. One could not make that claim for the 1346-to-1350 plague pandemic, which is credited with

helping to end feudalism in Western Europe by raising the negotiating power of laborers. But this event, which killed perhaps one-third of Europe's population, was of unique intensity.

A final consideration with respect to the economic implications of nature's shocks is the possibility of "creative destruction," a notion developed by the Austrian economist Joseph Schumpeter. Schumpeter had in mind business cycle crashes and disruptive innovations when he coined this phrase in 1942 to refer to a phenomenon in which bankruptcies eliminated inefficient enterprises, freeing up resources for more efficient use. Taking the response to the plague pandemic in Europe as an inspiration, it is possible to imagine that in the long run, brutal destruction of existing infrastructure and business plant could clear the way for a new generation of more efficient investment. This optimistic perspective, it must be said, assumes that a shock is followed by a time of stability and other favorable conditions. The great Lisbon earthquake of 1755 cleared the way for a more economically rational city plan in subsequent years, but it is anything but clear that post-Katrina New Orleans will feature more economically efficient business plant and infrastructure—although the opportunity surely exists.[20] In any event, recurrent shocks would prohibit creative destruction even if other circumstances were favorable.

Political and social effects of nature's shocks defy quantitative measure, and all conclusions about them are tentative and subject to dispute. Nevertheless, some generalizations seem reliable.

First, nature's shocks in the past have proved simultaneously socially divisive and unifying. This is easily visible in the Katrina disaster. In the wake of the storm, looting was widespread and citizens preyed upon one another in various disturbing ways.[21] Moreover, the challenges of responding to a disaster on that scale exacerbated political and social cleavages, as various officials and groups blamed one another for mismanagement—not without cause. At the same time, however, citizens throughout the United States donated money, materials, and labor in solidarity with the Katrina victims, as did populations in dozens of countries overseas. Such paradoxical responses are probably the norm.

Second, social conflict on some scale was routine during and after disasters. Societies with little in the way of safety net, such as, say, Ethiopia in the 1970s and 1980s, easily succumbed to banditry, ethnic and religious violence, and even outright civil war under the stress of acute drought.[22] Restraint and civility can quickly perish when people are confronted with imperious necessity. This much has been obvious to observers since Thucydides' analysis of the Corcyran Revolution, during the Peloponnesian War.

Third, political reaction to shocks often took the form of scapegoating minorities or foreigners. The Black Death in Europe intensified persecution of Jews, who were accused of poisoning wells and causing the pestilence. This played some role in encouraging Jewish migration to eastern Europe in the fourteenth century.[23] After the great 1923 Kanto earthquake in Japan, which killed some 130,000 to 150,000 people, vigilante mobs together with army and police units attacked Tokyo's Korean community, then about 30,000 strong, and killed perhaps 6,000. Many Japanese believed rumors that Koreans had set fires and poisoned water supplies in the earthquake's aftermath.[24]

Fourth, in the wake of disasters, government authorities have frequently been the target of popular wrath, either for neglect or for intrusive efforts to minimize or prevent damage. This is by and large a modern phenomenon, a reflection of the state's assumption of responsibility for public health and order. Cholera epidemics in nineteenth-century Europe intensified divisions within society and contributed to the revolutionary spirit of the 1830-to-1871 era. Cholera was a fearsome scourge that killed quickly and seemed to come out of nowhere—it is communicated by a bacillus that thrives in warm water and originally came from South Asia. Urban populations with unsanitary water were especially victimized, which in the context of the times fueled the widespread belief that the upper classes or the state were systematically poisoning the poor. Government efforts at quarantines, compulsory hospitalization, and cordons sanitaires provoked riots and attacks on state officials. Even though popular reactions to cholera and to state efforts to control it in France cannot be said to have caused the revolutions of 1830 or 1848, they surely contributed to the distrust of authorities and class antagonisms that underlay these uprisings.[25] Echoes lasted as late as the cholera epidemic in Apulia, Italy, in 1910 and 1911; the authorities reacted by encouraging pogroms against Gypsies (a minority deeply unpopular among other segments of Italian society and with the Italian state) and by forcibly detaining and isolating the sick. Italians responded by persecuting the Gypsies, but also by rioting and killing medical officials, which led the government to call in the army.[26]

In the course of the nineteenth and early twentieth centuries, states took more and more responsibility for public health. Compulsory inoculation against smallpox, pioneered by George Washington in the Continental Army, set an example that inspired much imitation once vaccines were developed against commonplace diseases. (The Revolutionary War might have been lost if Washington had not taken this step.)[27] Yet popular resistance to such

measures persisted. In Rio de Janeiro, in 1904 to 1905, poor neighborhoods revolted against public health campaigns involving smallpox vaccination and mosquito control as a measure against yellow fever.[28]

In colonial contexts this sort of political turmoil as a reaction to government efforts to check epidemics or other natural disasters was often still more pronounced, and rumors of deliberate biological warfare against the poor, more frequent. In colonial Mexico, droughts often preceded peasant uprisings, not merely because drought meant hunger but also because at such times the distribution of irrigation water seemed especially unfair, whereas in times of plentiful rainfall it mattered less.[29] In colonial East Africa, efforts to control outbreaks of sleeping sickness that involved resettlement schemes, quarantine of livestock, and other intrusive measures regularly provoked local rebellions against British rule.[30] Along the coast of West Africa, in the area that is now southeastern Ghana, coastal erosion, which the colonial government declined to deal with, helped push the local population into political resistance to colonial rule.[31] British efforts to improve public health in colonial India, and especially to contain the many epidemics of the years 1890 to 1921, frequently ran afoul of local sensibilities and aroused ire that easily translated into political resistance.[32] In the right social and political circumstances, natural shocks, and perceptions of official reactions to them, could precipitate resistance and rebellion.

In one sense, this was nothing new. In most precolonial African societies, and also in imperial China before 1911, populations normally believed that proper ecological functioning—meaning the absence of floods, droughts, epidemics, and so forth—depended on a proper relationship between their rulers and heavenly powers. Natural shocks, therefore, represented a breakdown in that relationship and an inevitable loss of moral authority for rulers. Floods and droughts were taken to mean rulers had lost their efficacy—had lost the "mandate of heaven," in Chinese parlance—and thus no longer were owed obedience. This obviously invited political turmoil.

In the nineteenth and twentieth centuries, when national governments increasingly sought and took responsibility for disease control, flood control, drought relief, and so forth, they inadvertently put themselves in the vulnerable position of the Chinese emperors. If natural shocks were not properly managed or, in some instances, if they were not prevented, the blame lay with the state. Legitimacy became hostage to the whims of nature. So while states improved their capacity to deal with nature's shocks, they were held to ever higher standards, expected to cope effectively with them, but not to intrude too deeply upon citizens' lives and lifestyles. At times rulers invited trouble by

encouraging lofty expectations. In 1857, when Napoleon III, the emperor of France, addressed parliament, he had the great Alpine floods of 1856 as well as the revolutions of 1848 on his mind: "By my honor, I promise that rivers, like revolution, will return to their beds and remain unable to rise during my reign."[33] Such boasts did nothing to enhance his moral authority.

The political significance of nature's shocks normally played out on a local or national scale and touched international politics only indirectly. When they did affect international politics, they exhibited the same paradoxical power to bring nations together and to push them into conflict.

Natural disasters have occasionally provoked outpourings of sympathy, both among populations and among states, since at least the eighteenth century. A notable recent example came in August and September 1999, when earthquakes hit first Izmit, in Turkey, and then a suburb of Athens. The Greek government was the first to come to the aid of Turkish earthquake victims, and weeks later the Turks reciprocated. Ordinary Greeks and Turks donated money and supplies to help earthquake victims in the other country. This occurred against a backdrop of long enmity between the governments and populations and helped considerably in defusing a long-simmering rivalry and reorienting politics across the Aegean. Of course, political conditions had to be favorable for a rapprochement before earthquake diplomacy could yield such results: in an era of saber rattling, the governments involved would not have cooperated and would have prevented rather than encouraged generosity on the part of ordinary Greeks and Turks.

Epidemics, while providing plenty of opportunity for mutual recrimination, probably brought states together more often than they drove them apart. The obvious rewards to international cooperation in disease control put the incentives clearly in favor of harmonized actions wherever possible, and against giving vent to frustrations with inadequate measures taken by neighboring states. Since the establishment of the International Red Cross, the World Health Organization, and other such global and regional entities, the multinational integration of disease control efforts has become routine and rarely has been the occasion for conflict. One partial exception to this rule is the position taken by Thabo Mbeki and some other South Africans on HIV/AIDS, which they sometimes attributed to malevolence on the part of Americans and Europeans.[34] Even this, however, did not fundamentally affect relations between South Africa and the West.

Sometimes, of course, nature's shocks exacerbate international or intersocietal conflicts. Earthquakes, hurricanes, and volcanic eruptions have rarely, if ever, had this effect because they are so localized in their damage.

Droughts are another matter. The greatest revolt in the history of Spanish America, that of Tupac Amaru in the Andes from 1780 to 1782, coincided with one of the worst droughts of the millennium, a result of the powerful recurring El Niño current. Thousands of desperate peasants rallied to his standard, which in better times would have appealed to far fewer. In another dramatic case, drought in southern Africa in the decade between 1820 and 1830 converted routine competition for grazing land and food into systemic conquests of the weak by the strong. The *mfecane* ("crushing") created a torrent of refugees throughout southern Africa and resulted in the formation of powerful new states, such as the Zulu kingdom.[35] Drought was also a spur to the slave-raiding that fed the Atlantic slave trade between 1550 and 1850: when food was scarce, one of the few ways to get it was to capture people and trade them for food from afar. Indeed, progressive desiccation—secular climate change in the West African Sahel—drove mounted slave raiders to penetrate deeper and deeper into West Africa in the years after 1600.[36]

Throughout the semiarid zones of the world, where drought was a regular risk, pastoralists and cultivators often uneasily shared frontier zones. Droughts, plagues of locusts, or any natural shock created desperation and drove otherwise peaceful communities to attack their neighbors in hopes of taking their food, livestock, or marketable possessions; and weakness born of drought or some other shock aroused the cupidity of nearby peoples or states suddenly presented with an easy opportunity to raid neighboring communities. The most common format for such violence was attacks by pastoralists upon settled villages, a common pattern in world history in semiarid areas from Manchuria to Senegal. Such attacks of course also took place without the provocation of drought, but drought made them more frequent. In medieval times in northern Syria and Iraq environmental shocks of one sort or another came once every five or six years on average, and often brought political violence in their wake. Villagers had every reason to support a strong state in hopes of keeping marauding pastoralists in check.[37]

While drought was probably the most politically dangerous of all nature's shocks in the deeper past, in the last hundred years water management schemes have often blunted its impact. Moreover, violent political conflict has become more often the affair of states with large urbanized populations rather than pastoral tribes and confederacies, and such states have found it imprudent to go to war to resolve problems created by drought. Even the potentially divisive cases of international river basins such as the Indus, the Mekong, or the Nile have so far been the subject of successful diplomacy

rather than military conflict. Observers in recent decades have often foreseen "water wars," in these and other contexts, but it has yet to happen, and indeed it has not happened for several millennia, if ever.[38] The historical record suggests that with well-organized states, the probability of warfare arising from drought-induced water shortage is low; the risk rises in the presence of weak states within which those components of society most aggrieved by drought are less constrained in their responses.

Before departing the subject of political reverberations from nature's shocks it is worth considering whether or not there is an analogue to Schumpeterian creative destruction in the political realm. Can natural shocks shake a society and state out of harmful complacencies and create the political will to undertake needed reforms? Can they discredit the least efficient parts of the political apparatus so thoroughly as to create new space for the more efficient? Perhaps, if conditions already exist for reform and if the gales of destruction are not so powerful as to destroy the state entirely. In the United States, for example, the Dust Bowl of the 1930s gave rise to a useful reform in the creation of the Soil Conservation Service, which has helped prevent the recurrence of catastrophic erosion on the scale of the 1930s, despite droughts in subsequent decades that were equally or more severe. The 1755 earthquake in Lisbon provided the Marques de Pombal with an opportunity to push through fundamental reforms in Portugal. The bubonic plague that harrowed Russia in the 1770s and the cholera epidemics of nineteenth-century Europe both led to major reform efforts in municipal and national governments. Disappointing responses to hurricanes in nineteenth-century Cuba had similar effects.[39] This may amount to a small silver lining in the dark cloud of natural disaster, in the same way that losing a war or undergoing economic depression has served as a spur for reform—provided something survived to be reformed.

Religious turbulence has long been a normal social reaction to nature's shocks. Throughout history most people understood plagues, hurricanes, droughts, and other disasters as divinely ordained or the work of evil people with supernatural powers. Hence, extraordinary natural shocks often brought heightened religiosity, either in the form of more intense devotion to traditional religions or more defections to innovative religions or cults. The rise of the Lotus Sect (Nichiren Buddhism) in Japan was abetted by a great earthquake in Kamakura, one of Japan's chief Buddhist centers, in 1257. The recurrent bubonic plague epidemics in Europe after 1348 gave rise to all manner of eccentric religious practices, most famously a sect of self-flagellants who when not occupied murdering Jews and clergymen wandered about

rending their flesh in imitation of Jesus' sufferings. The Neapolitan cult of San Gennaro derives from the experience of 1631, when Naples was spared destruction by a great eruption of Mount Vesuvius. In the United States, the New Madrid earthquakes of 1811 and 1812, following on serious floods in the Ohio and Mississippi basins, helped the prophet Tecumseh, who allegedly had predicted the earthquakes, rally Native Americans to his religious war against the United States. They also prompted many white Americans to experiment with eccentric religious doctrines.[40] The severe drought of 1991 and 1992 in Zimbabwe, often called the worst in living memory, gave rise to at least three charismatic religious movements as Zimbabweans found divine explanations for their misfortunes more satisfying than hypotheses about perturbations in the atmosphere's Intertropical Convergence Zone.[41]

There is rarely a shortage of people charismatic and persuasive enough to make a convincing case—to those ready to be convinced—that any extraordinary event is a sign that radical religious reform is needed. It would be interesting to know whether the Katrina disaster brought an upsurge in religiosity along the Gulf Coast. In any case, if the future holds more serious extreme weather events in store, it seems likely that the most extreme will generate new forms of religion and intensified commitment to old ones.

A Glance at the History of Technological and Social Change

If we are to stop loading the atmosphere with greenhouse gases, we must either find a technological fix or radically reduce energy usage. The history of technological change in modern times is a bit like the punctuated-equilibrium model of evolutionary biology: there are periods of minimal change interspersed with moments of torrential change. Changes tend to come in clusters. The reason for this is that new technologies, to be widely adopted, must fit in not only with existing and emerging technologies but also with existing and emerging institutional, political, economic, and social frameworks—the "software" of society. Technologies coevolve both with other technologies and with this "software."

This is an encouraging perspective in the sense that it means sudden change might occur at any point. It is discouraging in the sense that it is hard to precipitate technological change; it comes when conditions are conducive, but not until then. The trick is to make conditions more conducive: to use policy to alter the "software" and tweak the technological hardware of society so as to speed the probability of new technologies' acceptance in the arenas of energy use and carbon sequestration.

Indeed, any steps to raise the tempo of technological change would likely be helpful on the climate change front. That is because in times past new technologies were adopted (selected, one might say, to use a Darwinian term) for many things, but not for being environmentally helpful—at least, not until very recently. Today, however, and in the foreseeable future, new technologies are unlikely to be adopted if they are environmentally malign; there is, for the first time in history, a "green filter" that skews the process of technological change. This filter exists partly as a matter of regulatory policy, but partly as an ideological force felt in most, if not all, spheres of society. It is likely to be durable, unless the problems of climate change, and of the environment generally, somehow are resolved. It is well to remember, however, that the process by which one technological cluster (say, that of oil, automobiles, and plastics) replaces an earlier one (iron, coal, railroads) is so complicated that it is impossible to produce on schedule or on demand. Further complicating things, a new cluster may take shape quickly in one location, but the speed of its global spread is another matter.[42]

If technology does not come to the atmosphere's rescue and our own, might social change do the trick? This would require changes in behavior that ratchet down energy use, or at least fossil fuel use. History is deeply discouraging on this front. There are very few examples anywhere of societies (as opposed to hermits and monks) that voluntarily renounced the fruits of high-energy society, or embraced a lower standard of living, as lower energy use, absent gains in efficiency, implies. One might claim that the early Christians embraced poverty, but they were a small minority within Roman society, and the great majority of them were poor to begin with.

Sometimes the abolition of slavery is offered as an example of an altruistic social movement that put moral concerns ahead of economic self-interest. Abolition of the slave trade within the British Empire took about thirty years to achieve; abolition of slavery nearly sixty. It took time to build the political coalitions necessary to overcome the self-interest of Caribbean slaveowners, an entrenched lobby well represented in London's Parliament. The effort involved decades of public relations campaigning, undertaken mainly by men of the cloth, as well as routine pork-barrel politics and logrolling, to use the American terms. Within the United States it took longer and took a war; and as a worldwide movement the abolition of slavery took longer still and required the forcible imposition of external values and morals upon African and Arab societies in which slavery had a long tradition of moral justification.

Abolition was indeed a remarkable development: slavery existed for at least 5,000 years and was nearly totally eliminated within 150. But the economic logic of slavery had begun to wane for a number of reasons when abolition gathered momentum as a social movement, and its global success required the moral and military dominance of nineteenth-century Britain and the self-confidence within British society to force abolition upon unwilling societies and cultures—a constellation of circumstances not easily reproduced. What this example really shows is how exceptional, and how contingent upon economic and political circumstances, the abolition of slavery really was. We could wait a long time for the stars to align themselves just right so as to permit a social movement that would lead to reduced energy use.

It remains theoretically possible that international accords might be reached that would limit the emission of greenhouse gases, as was done with chlorofluorocarbons beginning in 1989. But the odds are against it, for a number of reasons. The ozone accords were low-hanging fruit. Technological alternatives proved easy to find and were manufactured by the biggest CFC-producing firms. CFCs were useful, but amounted to a tiny part of any economy compared with fossil fuels. Only a handful of countries made them. And atmospheric scientists could make a strong case that ozone depletion formed a direct threat to human health in the form of higher risks of skin cancer. While initially CFC manufacturers denied the truth of the science, this phase lasted only briefly. As the unfruitful negotiations over carbon emissions and climate change since the early 1990s show, limiting greenhouse gases is inherently a tougher diplomatic nut to crack.

The Unprecedented Challenge Ahead

History does not tell us much of anything directly about social and political responses to climate change. Abrupt climate change is too far back in the past, when societies were too different from our own, to shed any light on the matter. More recent climate change, when societies were more closely comparable to ours, was too gradual, usually too slow to be noticed. Even the arrival of warmer centuries from 900 to 1200 C.E., known as the Medieval Optimum, and the cooling of the Little Ice Age went undetected at the time.

Widening the lens to consider natural shocks of several sorts, as this chapter does, is a bit more helpful. Such shocks have been part of the ordinary experience of most generations until very recently. The most serious were epidemics and droughts—both of which climate modelers anticipate will become more likely in a greenhouse world. Resilience in the face of such shocks originally consisted mainly of mobility and simplicity of the

way of life but within the last two centuries came to rest more and more on bureaucratic provisions for disaster and technological means to prevent or mitigate it.

The ability to do this well was, and is, very unevenly distributed around the world. Assuming that such shocks become more common in the future, the ability to generate and provide resilience, in whatever form, will become an ever greater force in determining the fates of societies and states. The degree to which international institutions master the necessary skills and execute them reliably and equitably will play an ever larger role in determining the levels of tensions within the international system.

The demographic and economic effects of nature's shocks, while often locally or regionally devastating, normally came to little on the global scale. The plague pandemic of the fourteenth century is the greatest exception. In certain circumstances, sizable shocks could have serious politically disruptive and destabilizing effects within societies and occasionally contributed to conflict between societies. Nature's shocks also routinely nudged along processes of social change, and occasionally more than that, notably in the field of religion. To judge by the record of the past, one should expect a greenhouse world to be a bit more volatile politically: stable nation-state regimes will be harder to build and maintain and internationalism will be subject to strains somewhat greater than would otherwise be the case, but with a significant countercurrent pushing toward greater cooperation in the face of common threats. And one should expect stronger religious enthusiasm than has ordinarily prevailed in modern history.

Conclusion

So can history help us with global warming? Yes and no. Yes in the sense that in the long record of human history there have been certain consistent elements in human beings' myriad responses to environmental disasters. Those elements—intensified conflict, deeper cooperation, political rebelliousness, religious zeal—appear in varying mixes, depending on the character of any given disaster and on social and political frameworks involved. The answer also has to be no, however, given that past disasters occurred on a relatively limited or discrete scale, particularly in recent years. There is no precedent in human history for a global disaster that affects whole societies in multiple ways at many different locations all at once. It is very difficult to predict how the past might inform the present and the future when it comes to climate change as a global phenomenon. But the effects of climate

change will play out simultaneously on several scales, and some of its likeliest consequences—enhanced drought and flooding, for example—will in the future, as in the past, be felt locally and regionally rather than globally. Thus, the more one unpacks the concept of climate change into its components, the more the record of the past becomes relevant to imagining the future.

Notes

1. Recent accounts of Holocene climate that are easily accessible to nonspecialists include Eugene Linden, *The Winds of Change: Climate, Weather and the Destruction of Civilization* (New York: Simon & Schuster, 2006); Brian Fagan, *The Long Summer: How Climate Changed Civilization* (New York: Basic Books, 2004). Somewhat more technical are William James Burroughs, *Climate Change in Prehistory: The End of the Reign of Chaos* (Cambridge University Press, 2005); Douglas MacDougall, *Frozen Earth: The Once and Future Story of Ice Ages* (University of California Press, 2004).

2. The best study remains Jean Grove, *The Little Ice Age* (Cambridge University Press, 1988).

3. William H. McNeill, *Plagues and Peoples* (New York: Doubleday, 1976) remains the most useful survey of disease history.

4. On the AIDS epidemic mortality, see Kenneth Mayer and H. S. Pizer, *The AIDS Pandemic: Impact on Science and Society* (New York: Academic Press, 2004), p. 2.

5. For higher figures, see Mike Davis, *Late Victorian Holocausts: El Niño and the Making of the Third World* (London: Verso, 2002).

6. V. K. Sharma and A. D. Kaushik, "Floods in India" (www.nidm.net/Chap6.htm); Xia Jun and Y. D. Chen, "Water Problems and Opportunities in the Hydrological Sciences in China," *Hydrological Sciences* 46, no. 6 (2001): 907–21; Gerd Tetzlaff and others, "Das Jahrtausendhochwasser von 1342 am Main aus meteorologisch-hydrologischer Sicht," *Wasser und Boden* 54 (2002): 41–49.

7. I purposefully omit mention of the flood in Johnstown, Pennsylvania, in 1889, a case of a burst dam, which killed 2,200. This I consider not one of nature's shocks but a case of engineering failure.

8. Jelle Zeilinga de Boer and Donald S. Sanders, *Earthquakes in Human History* (Princeton University Press, 2005). By far the most serious eruption, from the human point of view, took place around 74,000 years ago, at Lake Toba, Sumatra. This eruption ejected 2,800 times as much material as Mount St. Helens, covered Malaysia in up to 9 meters (30 feet) of ash, put 10 billion tons of sulfuric acid into the atmosphere (producing acid rain of a unique intensity), lowered global temperatures by 3 to 4°C (5 to 7°F), and, according to one interpretation of mitochondrial DNA evidence, brought the human race to the brink of extinction. This was the biggest eruption of the past 2 million years.

9. Of course, the rich world has since 1919 lived with the specter of war and since the 1940s with the risk of nuclear annihilation.

10. Mark Cioc, *The Rhine: An Eco-Biography* (University of Washington Press, 2002); David Blackbourn, *The Conquest of Nature: Water, Landscape, and the Making of Modern Germany* (New York: Norton, 2005).

11. Jacques Dupâquier and others, *Marriage and Remarriage in Populations of the Past* (London: Academic Press, 1981).

12. Pierre-Etienne Will and R. Bin Wong, *Nourish the People: The State Civilian Granary System in China, 1650–1850* (University of Michigan Center for Chinese Studies, 1991). When Henry Wallace read of this system in a Columbia University dissertation on Confucian economics of 1911, he drew inspiration that informed his policies as Secretary of Agriculture under Franklin Roosevelt, and helped shape the mission of the UN's Food and Agriculture Organization.

13. Matthew Mulcahy, *Hurricanes and Society in the British Greater Caribbean, 1624–1783* (Johns Hopkins University Press, 2006); Zeilinga de Boer and Sanders, *Earthquakes in Human History,* p. 128; and David P. Forsythe, *The Humanitarians* (Cambridge University Press, 2005).

14. Cormac Ó Gráda, "Making Famine History," *Journal of Economic Literature* 45 (2007): 5–38.

15. Tim Flannery, *The Future Eaters* (New York: Baziller, 1994).

16. J. R. McNeill, *Something New under the Sun* (New York: Norton, 2000), p. 361, based on Angus Maddison, *Monitoring the World Economy* (Paris: OECD, 1995).

17. City of Kobe, "The Great Hanshin-Awaji Earthquake Restoration Project: Statistics and Restoration Progress" (2005) (http://www.greenbar.org/kobestats.htm).

18. Presumably more was spent on drought relief at state and local levels. Western Governors Association, "Western Drought Facts and Information 2004" (www.westgov.org/wga/testim/drought-fact04.pdf). See also W. E. Riebsame, S. A. Changnon, and T. R. Karl, *Drought and Natural Resources Management in the United States: Impacts and Implications of the 1987–89 Drought* (Boulder, Colo.: Westview Press, 1991).

19. Holli Riebeek, "The Rising Cost of Natural Hazards," report, March 28, 2005, NASA's Earth Observatory (earthobservatory.nasa.gov/Study/RisingCost/printall.php).

20. William L. Waugh and R. Brian Smith, "Economic Development and Reconstruction on the Gulf after Katrina," *Economic Development Quarterly* 20 (2006): 211–18.

21. See "Storm and Crisis: Lawlessness," *New York Times,* September 25, 2005, p. A1, which offers an initial assessment of the uptick in assaults, rapes, and murders that took place. The numbers cannot be verified because of the breakdown in policing, in emergency services, and in hospital record keeping.

22. Sven Rubenson, "Environmental Stress and Conflict in Ethiopian History: Looking for Correlations," *Ambio* 20 (1991): 179–82.

23. Catherine Park, "The Black Death," in *The Cambridge World History of Human Disease,* edited by K. N. Kiple (Cambridge University Press, 1993), pp. 612–15.

24. Zeilinga de Boer and Sanders, *Earthquakes in Human History,* pp. 188–89. Details available in Sonia Ryang, "The Great Kanto Earthquake and the Massacre of Koreans in 1923: Notes on Japan's Modern National Sovereignty," *Anthropological Quarterly* 76, no. 4 (2003): 731–48.

25. Louis Chevalier, ed., *Le choléra: la première épidémie du XIX siècle* (La Roche-sur-Yon, 1958); and Richard Evans, "Epidemics and Revolutions: Cholera in Nineteenth-Century Europe," in *Epidemics and Ideas: Essays in the Historical Perception of Pestilence,* edited by Terence Ranger and Paul Slack (Cambridge University Press, 1992): 149–73.

26. Frank Snowden, *Naples in the Time of Cholera, 1884–1911* (Cambridge University Press, 1995).

27. Elizabeth Fenn, *Pox Americana: The Great Smallpox Epidemic of 1775–1782* (New York: Hill & Wang, 2001).

28. N. Sevcenko, *A revolta da vacina: mentes insanas em corpos rebeldes* [The vaccination revolt: insane minds in rebellious bodies] (São Paulo: Scipione, 1993).

29. Georgina Enfield, *Climate and Society in Colonial Mexico: A Study in Vulnerability* (London: Routledge, forthcoming, 2008); D. S. Brenneman, "Climate of Rebellion: The Relationship Between Climate Variability and Indigenous Uprisings in Mid-Eighteenth-Century Sonora," Ph.D. dissertation, University of Arizona, 2004.

30. Kirk Hoppe, *Lords of the Fly: Sleeping Sickness Control in British East Africa, 1900–1960* (Westport, Conn.: Praeger, 2003).

31. Emmanuel Akyeampong, *Between the Sea and the Lagoon: An Ecohistory of the Anlo of Southeastern Ghana* (Ohio University Press, 2001).

32. David Arnold, *Colonizing the Body: State Medicine and Epidemic Disease in Nineteenth-Century India* (University of California Press, 1993).

33. Quoted in Michael Bess, *The Light-Green Society: Ecology and Technological Modernity in France, 1960–2000* (University of Chicago Press, 2003), p. 57.

34. Theodore F. Sheckels, "The Rhetoric of Thabo Mbeki on HIV/AIDS: Strategic Scapegoating?" *Howard Journal of Communications* 15 (2004): 69–82.

35. Elizabeth Eldredge, "Sources of Conflict in Southern Africa, c. 1800–1830: The Mfecane Reconsidered," *Journal of African History* 33 (1992): 1–35.

36. James Webb, *Desert Frontier: Ecological and Economic Change along the Western Sahel, 1600–1850* (University of Wisconsin Press, 1994); Joseph Miller, *The Way of Death: Merchant Capitalism and the Angolan Slave Trade, 1730–1830* (University of Wisconsin Press, 1988).

37. Magnus Widell, "Historical Evidence for Climate Instability and Environmental Catastrophes in Northern Syria and the Jazira: The Chronicle of Michael the Syrian," *Environment and History* 13 (2007): 47–70. The data used here are from 600 to 1200 C.E. The broader pattern was described in the fourteenth century by Ibn Khaldun, *The Muqaddimah* (Princeton University Press, 1967), based on his experiences in North Africa.

38. Sandra Postel and Aaron Wolf, "Dehydrating Conflict," *Foreign Policy* 126 (September–October 2001): 60–67; Thomas Homer-Dixon, "On the Threshold: Environmental Changes as Causes of Acute Conflict," *International Security* 16 (Autumn 1991): 76–116; Thomas Homer-Dixon, "Environmental Scarcities and Violent Conflict," *International Security* 19 (1994): 5–40.

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40. Zeilinga de Boer and Sanders, *Earthquakes in Human History*, pp. 133–35, 190–92; James L. Penick, *The New Madrid Earthquakes* (University of Missouri Press, 1981), pp. 111–26.

41. Hezekiel Mafu, "The 1991–1992 Zimbabwean Drought and Some Religious Reactions," *Journal of Religion in Africa* 25 (1995): 288–308.

42. David Egerton, *The Shock of the Old: Technology in Global History since 1900* (Oxford University Press, 2007).

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Three Plausible Scenarios of Future Climate Change

Jay Gulledge

This chapter reviews projected climate change impacts over the next thirty to one hundred years and outlines three climate change scenarios, of three grades of severity, that cover a plausible range of impact severity. These scenarios, based on current scientific understanding and uncertainty regarding past and future climate change, guide assessments in later chapters of potential security consequences of climate change impacts. The general approach is to settle on three different levels of global average temperature change for each scenario, and then extract relevant projected impacts from the *Fourth Assessment Report* (*AR4*) of the Intergovernmental Panel on Climate Change (IPCC) and other peer-reviewed scientific sources. We focus particularly on changes in freshwater resources, crop production, extreme weather events, sea level rise, and the meridional overturning circulation (MOC) of the North Atlantic Ocean.

Because the purpose of this project is to assess potential security risks of future climate change, the primary criterion for the climate impacts scenarios outlined here is *plausibility* rather than *probability*. Rather than asking, What is the most likely climate-driven outcome? we ask, *What potential climate-driven outcomes are plausible, given current scientific understanding and uncertainties about the future climate?* Recent observations indicate that

The scenarios outlined in this section are not predictions of future conditions and should not be read or cited as such.