from Lester R. Brown, *Plan B 2.0 Rescuing a Planet Under Stress and a Civilization in Trouble* (NY: W.W. Norton & Co., 2006).

4

Rising Temperatures and Rising Seas

In 2004, Sir David King, the U.K. government's Chief Scientific Advisor, reported some revealing new research confirming the relationship between carbon dioxide (CO_2) levels and temperature over the last 740,000 years. Analysis of an Antarctic ice core drilled to a depth of three kilometers by British scientists showed that the atmospheric concentrations of CO_2 consistently fluctuated between 200 parts per million (ppm) during the ice ages and 270 ppm during the warm intervals. This shift from ice age to warm period occurred many times and always within this CO_2 range.[1]

When the Industrial Revolution began, the atmospheric CO_2 level was roughly 270 ppm. The 377 ppm registered for 2004 is not only far above any level over the last 740,000 years, it may be nearing a level not seen for 55 million years. At that time the earth was a tropical planet. There was no polar ice; sea level was 80 meters (260 feet) higher than it is today.[2]

The destructive effects of higher temperatures are visible on many fronts. Crop-withering heat waves have lowered grain harvests in key food-producing regions in recent years. In 2002, record-high temperatures and associated drought reduced grain harvests in India, the United States, and Canada, dropping the world harvest 90 million tons, or 5 percent below consumption. The record-setting 2003 European heat wave contributed to a world harvest shortfall of 90 million tons. Intense heat and drought in the U.S. Corn Belt in 2005 contributed to a world shortfall of 34 million tons.[3]

Such intense heat waves also take a direct human toll. In 1995, 700 residents of Chicago died in a heat wave. In May 2002, in a heat wave in India that reached 50 degrees Celsius (122 degrees Fahrenheit), more than 1,000 people died in the state of Andhra Pradesh alone.[4]

In 2003, the searing heat wave that broke temperature records across Europe claimed 49,000 lives in eight countries. Italy alone lost more than 18,000 people, while 14,800 died in France. More than 15 times as many people died in Europe in this heat wave as died during the terrorist attacks on the World Trade Center and the Pentagon on September 11, 2001.[5]

Among the various manifestations of rising temperatures, ice melting and its effect on sea level are drawing scientists' attention. As sea level rises, low-lying island countries like Tuvalu and the Maldives and coastal cities like London, New York, and Shanghai will be among the first to feel the consequences.[6]

The insurance industry is painfully aware of the relationship between higher temperatures and storm intensity. As weather-related damage claims have soared, the last few years have brought a drop in earnings and a flurry of lowered credit ratings for both insurance companies and the reinsurance companies that insure them. Companies using historical records as a basis for calculating insurance rates for future storm damage are realizing that the past is no longer a reliable guide to the future.[7]

This is a problem not only for the insurance industry, but for all of us. We are altering the earth's climate, setting in motion trends we do not always understand with consequences we cannot anticipate.

Rising Temperature and Its Effects

Scientists at the National Aeronautics and Space Administration's Goddard Institute for Space Studies gather data from a global network of some 800 climate-monitoring stations to measure changes in the earth's average temperature. Their records go back 125 years, to 1880.[8]

Since 1970, the earth's average temperature has risen by 0.8 degrees Celsius, or nearly 1.4 degrees Fahrenheit. During this span, the rise in temperature each decade was greater than in the preceding one. (See Figure 4–1.) Meteorologists note that the 22 warmest years on record have come since 1980. And the six warmest years since recordkeeping began in 1880 have come in the last eight years. Three of these six—2002, 2003, and 2005—were years in which major food-producing regions saw their crops wither in the face of record temperatures.[9]

The amount of CO_2 in the atmosphere has risen substantially since the Industrial Revolution, with most of the rise coming since recordkeeping began in 1959. Since then it has risen every year, making this one of the world's most predictable environmental trends. As shown in Figure 4–2, CO_2 levels turned sharply upward around 1960. Roughly a decade later, around 1970, the temperature too began to climb.[10]

Against this backdrop of record increases, the projections of the Intergovernmental Panel on Climate Change (IPCC) that the earth's average temperature will rise 1.4–5.8 degrees Celsius (2.5–10.4 degrees Fahrenheit) during this century seem all too possible. Recent data on the temperature rise in some northern regions—such as Alaska, western Canada, and Siberia—cou-

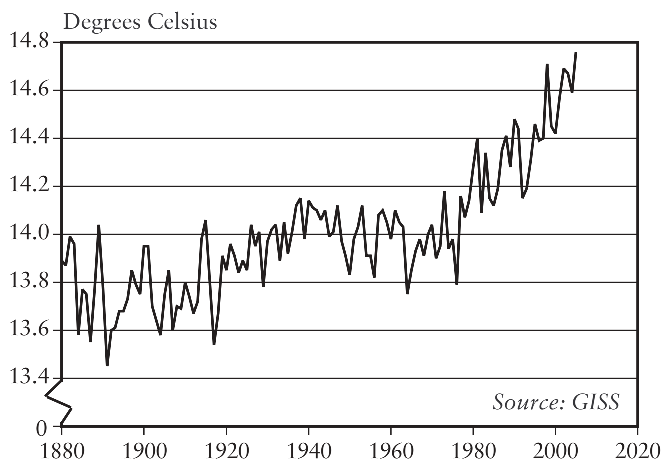

Figure 4–1. *Average Global Temperature, 1880–2005*

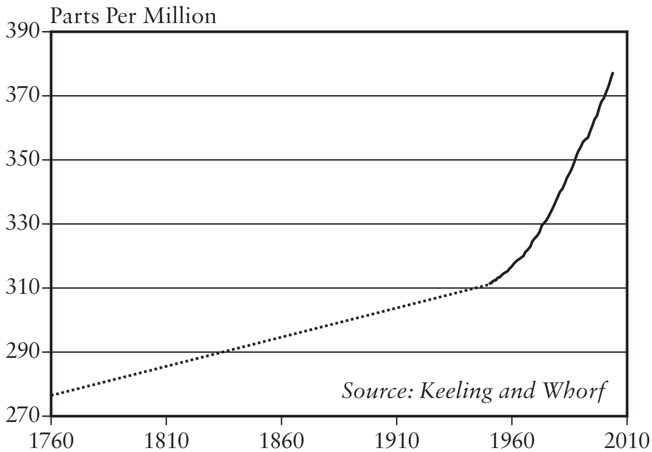

Figure 4–2. *Global Atmospheric Concentrations of Carbon Dioxide, 1760–2004*

pled with the accelerated melting of the Greenland ice sheet, the melting of glaciers in mountain ranges throughout the world, and the likelihood at this writing that the global temperature for 2005 will set yet another record high all suggest that the global temperature rise will be close to the upper end of the IPCC projected range. Such an increase—of 5.8 degrees Celsius by 2100, a rise comparable to that between the last Ice Age and today—will create a world far different from the one we know.[11]

At a practical level, the IPCC projected rise in temperature is a global average. In reality, the rise will be very uneven. It will be much greater over land than over oceans, in the higher latitudes than over the equator, and in the continental interiors than in coastal regions.[12]

Higher temperatures diminish crop yields, melt the snow/ice reservoirs in the mountains that feed the earth's rivers, cause more destructive storms, increase the area affected by drought, and cause more frequent and destructive wild fires.[13]

In a paper presented at the American Meteorological Society's annual meeting in San Diego, California, in January 2005, a team of scientists from the National Center for Atmospheric Research reported a dramatic increase in the earth's land surface affected by drought over the last few decades. They reported that the land experiencing very dry conditions expanded from less than 15 percent of the earth's total land area in the 1970s to roughly 30 percent by 2002. They attributed part of the change to a rise in temperature and part to reduced precipitation, with high temperatures becoming progressively more important during the latter part of the period. Lead author Aiguo Dai reported that most of the drying was concentrated in Europe and Asia, Canada, western and southern Africa, and eastern Australia.[14]

Researchers with the U.S. Department of Agriculture's Forest Service reported that even a 1.6-degree-Celsius rise in summer temperature could double the area of wildfires in the 11 western states. The study, published in the August 2004 issue of *Conservation Biology*, drew on 85 years of fire and temperature records.[15]

The National Wildlife Federation (NWF) reports that if temperatures continue to rise, by 2040 one out of five of the Pacific Northwest's rivers will be too hot for salmon, steelhead, and trout to survive. Paula Del Giudice, Director of the Federation's Northwest Natural Resource Center, notes that "global warming will add an enormous amount of pressure onto what's left of the region's prime cold-water fish habitat."[16]

Ecosystems everywhere will be affected by higher temperatures, sometimes in ways we cannot easily predict. The Pew Center for Global Climate Change sponsored a mega-study analyzing some 40 scientific reports that link temperature with changes in ecosystems. Among the many changes reported are spring arriving nearly two weeks earlier in the United States, tree swallows nesting nine days earlier than they did 40 years ago, and a northward shift of red fox habitat that has it encroaching on the Arctic fox's range. Inuits were surprised by the appearance of robins, a bird they had never seen before. Indeed, there is no word in Inuit for "robin."[17]

Hector Galbraith of the University of Colorado-Boulder, a co-author of the Pew study, indicated that "the effects of this change are occurring much more rapidly than . . . expected." He also said "that ecosystems are much more sensitive to climate change than believed a decade ago." A study sponsored by Conservation International has predicted that continued climate change could drive more than a quarter of all land animals and plants to extinction.[18]

Douglas Inkley, NWF Senior Science Advisor and senior author of a report to the Wildlife Society, notes, "We face the prospect that the world of wildlife that we now know—and many of the places we have invested decades of work in conserving as refugees and habitats for wildlife—will cease to exist as we know them, unless we change this forecast."[19]

The Crop Yield Effect

One of the economic trends most sensitive to higher temperatures is crop yields. Crops in many countries are grown at or near their thermal optimum, making them vulnerable to any rise in temperature. Even a relatively minor increase during the growing season of 1 or 2 degrees Celsius can shrink the grain harvest in major food-producing regions, such as the North China Plain, the Gangetic Plain of India, or the U.S. Corn Belt.[20]

Higher temperatures can reduce or even halt photosynthesis, prevent pollination, and lead to crop dehydration. Although the elevated concentrations of atmospheric carbon dioxide that raise temperature can also raise crop yields, the detrimental effect of higher temperatures on yields overrides the CO_2 fertilization effect for the major crops.

In a study of local ecosystem sustainability, Mohan Wali and his colleagues at Ohio State University noted that as temperature rises, photosynthetic activity in plants increases until the temperature reaches 20 degrees Celsius (68 degrees Fahrenheit). The rate of photosynthesis then plateaus until the temperature hits 35 degrees Celsius (95 degrees Fahrenheit), whereupon it begins to decline, until at 40 degrees Celsius (104 degrees Fahrenheit), photosynthesis ceases entirely.[21]

The most vulnerable part of a plant's life cycle is the pollination period. Of the world's three food staples—rice, wheat, and corn—corn is particularly vulnerable. In order for corn to reproduce, pollen must fall from the tassel to the strands of silk that emerge from the end of each ear of corn. Each of these silk strands is attached to a kernel site on the cob. If the kernel is to develop, a grain of pollen must fall on the silk strand and then journey to the kernel site. When temperatures are uncommonly high, the silk strands quickly dry out and turn brown, unable to play their role in the fertilization process.

The effects of temperature on rice pollination have been studied in detail in the Philippines. Scientists there report that the pollination of rice falls from 100 percent at 93 degrees Fahrenheit (34 degrees Celsius) to near zero at 104 degrees Fahrenheit, leading to crop failure.[22]

High temperatures can also dehydrate plants. While it may take a team of scientists to understand how temperature affects rice pollination, anyone can tell when a cornfield is suffering from heat stress. When a corn plant curls its leaves to reduce exposure to the sun, photosynthesis is reduced. And when the stomata on the underside of the leaves close to reduce moisture loss, CO_2 intake is reduced, thereby restricting photosynthesis. At elevated temperatures, the corn plant, which under ideal conditions is so extraordinarily productive, goes into thermal shock.

Within the last few years, crop ecologists in several countries have been focusing on the precise relationship between temperature and crop yields. In an age of rising temperatures, their findings are disturbing. One of the most comprehensive of these studies was conducted at the International Rice Research Institute (IRRI) in the Philippines, the world's premier rice research organization. The team of eminent crop scientists there noted that from 1979 to 2003, the annual mean temperature at the research site rose by roughly 0.75 degrees Celsius.[23]

Using crop yield data from the experimental field plots for irrigated rice under optimal management practices for the years 1992–2003, the team's finding confirmed the rule of thumb emerging among crop ecologists—that a 1-degree-Celsius rise in temperature above the norm lowers wheat, rice, and corn yields by 10 percent. The IRRI finding was consistent with those of other recent research projects. The scientists concluded that "temperature increases due to global warming will make it increasingly difficult to feed Earth's growing population."[24]

While this study analyzing rice yields was under way, an empirical historical analysis of the effect of temperature on corn and soybean yields was being conducted in the United States. It concluded that higher temperatures had an even greater effect on yields of these crops. Using data for 1982–98 from 618 counties for corn and 444 counties for soybeans, David Lobell and Gregory Asner concluded that for each 1-degree Celsius rise in temperature, yields declined by 17 percent.

Given the projected temperature increases in the U.S. Corn Belt, where a large share of the world's corn and soybeans is produced, these findings should be of concern to those responsible for world food security.[25]

Two scientists in India, K.S. Kavi Kumar and Jyoti Parikh, assessed the effect of higher temperatures on wheat and rice yields. Basing their model on data from 10 sites, they concluded that in north India a 1-degree Celsius rise in mean temperature did not meaningfully reduce wheat yields, but a 2-degree rise lowered yields at almost all the sites. When they looked at temperature change alone, a 2-degree Celsius rise led to a decline in irrigated wheat yields ranging from 37 percent to 58 percent. When they combined the negative effects of higher temperature with the positive effects of CO_2 fertilization, the decline in yields among the various sites ranged from 8 percent to 38 percent. For a country projected to add 500 million people by midcentury, this is a troubling prospect.[26]

Reservoirs in the Sky

Snow/ice masses in mountains are nature's freshwater reservoirs—nature's way of storing water to feed rivers during the summer dry season. Now they are being threatened by the rise in temperature. Even a 1-degree rise in temperature in mountainous regions can markedly reduce the share of precipitation falling as snow and can boost that coming down as rain. This in turn increases flooding during the rainy season and reduces the snowmelt to feed rivers during the dry season.

In some agricultural regions, these "reservoirs in the sky" are the leading source of irrigation and drinking water. In the southwestern United States, for instance, the Colorado River—the primary source of irrigation water—depends on snowfields in the Rockies for much of its flow. California, in addition to depending heavily on the Colorado, also relies on snowmelt from the Sierra Nevada in the eastern part of the state. Both the Sierra Nevada and the coastal range supply irrigation water to California's Central Valley, the world's fruit and vegetable basket.

Preliminary results of an analysis of rising temperature effects on three major river systems in the western United States—the Columbia, the Sacramento, and the Colorado—indicate that the winter snow pack in the mountains feeding them will be dramatically reduced and that winter rainfall and flooding will increase accordingly.[27]

With a business-as-usual energy policy, global climate models project a 70-percent reduction in the amount of snow pack for the western United States by mid-century. A detailed study of the Yakima River Valley, a vast fruit-growing region in Washington state, by the U.S. Department of Energy's Pacific Northwest National Laboratory shows progressively heavier harvest losses as the snow pack shrinks, reducing irrigation water flows. A 2-degree-Celsius rise in temperature would reduce farm income in the valley by $92 million; a rise of 4 degrees Celsius would cut farm income by $163 million, nearly a quarter of the current harvest.[28]

In Central Asia, the agriculture in several countries—Uzbekistan, Turkmenistan, Kyrgyzstan, Kazakhstan, Tajikistan, and Afghanistan—depends heavily on snowmelt from the Hindu Kush, Pamir, and Tien Shan mountain ranges for irrigation water. Nearby Iran gets much of its water from the snowmelt in the 5,700-meter Alborz Mountains between Tehran and the Caspian Sea.[29]

Largest of all, where farmers are concerned, is the vast snow/ice mass in the Himalayas. Every major river in Asia, where half the world's people live, originates in the Himalayas, including the Indus, the Ganges, the Mekong, the Yangtze, and the Yellow. If warmer temperatures increase rainfall and reduce snowfall in the Himalayas, there will be more flooding during the rainy season and less snowmelt to feed rivers during the dry season.[30]

Reduced snow pack to feed the Yellow River flow will shrink China's wheat harvest, the largest in the world. Alterations in the flow of the Yangtze River will directly affect China's rice harvest—also the world's largest. And India's wheat harvest, second only to China's, will be affected by the flows of both the Indus and the Ganges. Anything that lowers the summer flow of the Mekong will affect the rice harvest of Viet Nam, a leading exporter.[31]

The shrinking of glaciers in the Himalayas could affect the water supply for hundreds of millions of people. In countries like India and China, the water stored during the rainy season as snow and ice for release in the dry season would be reduced or, in some cases, disappear entirely. The result would be more destructive floods alternating annually with more severe early summer water shortages.[32]

There are many more mountain ranges where snow/ice regimes are shifting, including the Alps and the Andes. The snow/ice masses in the world's leading mountain ranges and the water they store as ice and snow is taken for granted simply because it has been there since before agriculture began. Now that is changing. If we continue raising the earth's temperature, we risk losing these reservoirs in the sky on which cities and farmers depend.[33]

Melting Ice and Rising Seas

In its landmark third report, released in early 2001, the IPCC projected that sea level would rise during this century by 0.09–0.88 meters (4–35 inches) as a result of thermal expansion and ice melting. Numerous new studies during the four years since then indicate that the earth's ice cover is melting even faster than IPCC scientists projected.[34]

A 2002 study by two scientists from the University of Colorado's Institute of Arctic and Alpine Research showed that the melting of large glaciers on the west coast of Alaska and in northern Canada is accelerating. Earlier data had indicated that this melting was raising sea level by 0.14 millimeters per year, but new data for the 1990s show that the more rapid melting is now raising sea level by 0.32 millimeters a year—more than twice as fast.[35]

This study is reinforced by a U.S. Geological Survey (USGS) study that indicated glaciers are now shrinking in all 11 of Alaska's glaciated mountain ranges. An earlier USGS study reported that the number of glaciers in Glacier National Park in the United States had dwindled from 150 in 1850 to fewer than 50 today. The remaining glaciers are projected to disappear within 30 years, leaving future generations of visitors to puzzle over the park's name.[36]

Another team of USGS scientists, which used satellite data to measure changes in the area covered by glaciers worldwide, described an accelerated melting of glaciers in several mountainous regions, including the South American Andes, the Swiss Alps, and the French and Spanish Pyrenees.[37]

The melting of glaciers is gaining momentum throughout the Andes. Glaciologist Lonnie Thompson of Ohio State University reports that the Qori Kalis glacier, on the west side of the Quelccaya ice cap in the Peruvian Andes, shrank three times as fast each year from 1998 to 2000 as it did between 1995 and 1998. And the earlier rate, in turn, was nearly double the annual rate of retreat from 1993 to 1995. Thompson projects that the Quelccaya ice cap will disappear entirely between 2010 and 2020. In nearby Ecuador, the Antisana glacier, which supplies half of the water for Quito, has retreated nearly 100 meters in the last eight years.[38]

Bernard Francou, research director for the French government's Institute of Research and Development, believes that 80 percent of South American glaciers will disappear within the next 15 years. For countries like Bolivia, Peru, and Ecuador, which rely on glaciers for water for household and irrigation use, this is not good news.[39]

The European Alps are also suffering a meltdown. Scientists at Zurich University report that glaciers in Switzerland shrank by 1 percent from 1973 to 1985 but that the area covered shrank 18 percent between 1985 and 2000. They observed that "the changes could also impact tourism, a crucial pillar of the Swiss economy, as the country's scenic glacial valleys become barren and rocky." As the glaciers disappear and the snowline retreats upward, the winter ski season will shrink.[40]

Lonnie Thompson's studies of Kilimanjaro show that between 1989 and 2000, Africa's tallest mountain lost 33 percent of its ice field. He projected that its snowcap could disappear entirely by 2015. In March 2005, the *Guardian* in London reported: "Africa's tallest mountain, with its white peak, is one of the most instantly recognizable sites in the world. But as this aerial photograph shows, Kilimanjaro's trademark snowy cap, at 5,895 meters (19,340 feet), is now all but gone—15 years before scientists predicted it."[41]

The vast snow/ice mass in the Himalayas is also retreating. The Union Internationale des Associations d'Alpinisme reports that the glacier that ended at the base camp from which Edmund Hillary and Tenzing Norgay launched their history-making ascent of Everest in 1953 has retreated about 5 kilometers (3 miles). Geologist Jeffrey Kargel, who studies the

Himalayas, is not surprised by this. "That fits in with the general picture of what's happening in Nepal, India, Bhutan and, to a smaller extent, Tibet," he says.[42]

A recently completed study by a team of more than 50 U.S. and Chinese scientists over 26 years measured the accelerated melting of the glaciers in Western China. The study reported that the volume of China's 46,298 glaciers has shrunk by 5.5 percent in the past 24 years. The melting of glaciers in this region, as in most other areas of the world, has accelerated sharply since the early 1990s.[43]

Yao Tandong, a leading Chinese glaciologist and contributor to the study, predicted that two thirds of China's glaciers could be gone by 2060. Melting of the vast Himalayan ice fields, which contain more ice than any region outside of the poles, could dramatically raise sea level. Yao Tandong summarized the situation: "The full-scale glacier shrinkage in the plateau region will eventually lead to an ecological catastrophe."[44]

Another recent study, *Impacts of a Warming Arctic*, concluded that the Arctic is warming almost twice as fast as the rest of the planet. Conducted by the Arctic Climate Impact Assessment (ACIA) team, an international group of 300 scientists, the study found that in the regions surrounding the Arctic, including Alaska, western Canada, and Eastern Russia, winter temperatures have already climbed by 3–4 degrees Celsius (4–7 degrees Fahrenheit) over the last half-century. Robert Corell, chair of ACIA observes, "The impacts of global warming are affecting people now in the Arctic." This region, he says, "is experiencing some of the most rapid and severe climate change on Earth."[45]

In testimony before the U.S. Senate Commerce Committee, Sheila Watt-Cloutier, an Inuit speaking on behalf of the 155,000 Inuits who live in Alaska, Canada, Greenland, and the Russian Federation, described the Inuits' struggle to survive in the fast-changing Arctic climate as "a snapshot of what is happening to the planet." She called the warming of the Arctic "a defining event in the history of this planet." And she went on to say "the Earth is literally melting."[46]

The ACIA report described how the retreat of the sea ice has "devastating consequences for polar bears" whose very survival may be at stake. Also threatened are the ice-living seals, a basic food source for the Inuits.[47]

Higher Arctic temperatures are also thawing what had been perpetually frozen soils of the region. As the tundra thaws, it destabilizes and damages buildings, pipelines, and roads. The melting of the tundra has effects far beyond local structural problems. A report in *Science* says, "No one knows exactly how much carbon is locked up in boreal and alpine permafrost, but estimates range from 350 to 450 gigatons [billion tons]—perhaps a quarter to a third of all soil carbon. The big question is what will happen if even a fraction of this massive carbon store is liberated." This compares with the 7 billion tons of carbon that is emitted from burning fossil fuels each year.[48]

The scientists chronicling the warming of the Arctic are perhaps most concerned about the effect on Greenland. If all the ice in the Arctic Sea melts, it will not affect sea level because that ice is already in the water. But if the warming of the Arctic melts the Greenland ice sheet, which is a mile and a half thick in some places, sea level would rise by 7 meters (23 feet). Such a melting of the Greenland ice sheet would be measured in centuries, not years. Nonetheless, recent maps show rapid melting around the ice sheet's outer edges, particularly on the eastern coast.[49]

Scientists are concerned about the melting of the Greenland ice sheet not only because of its obvious effect on sea level, but also because it might disrupt ocean circulation, particularly the flow of the Gulf Stream. Under current conditions, the Gulf Stream that brings warm surface water northward from the South Atlantic supports Western Europe's mild climate. As the high-salinity warm water moves northward, it cools as a result of heat loss and evaporation, becoming more dense and salty. This eventually causes it to sink and then flow southward as deep water. An influx of fresh water from melting of the Greenland ice sheet or of Arctic sea ice could disrupt this circulation pattern, resulting in somewhat lower temperatures in the northeastern United States and eastern Canada and a sharp temperature drop in Europe. Historical evidence suggests that such shifts have sometimes come quickly—in a matter of years or decades.[50]

As the Arctic sea ice melts, it opens the possibility of using the Arctic Sea as a shipping route between the Atlantic and Pacific Oceans. The search for the Northwest Passage, a dream of early explorers who otherwise had to sail around the Cape of

Good Hope, could become a nightmare for our early twenty-first century society. Shipping companies are already looking at potential shortcuts. The trip from Europe to Asia via the Panama Canal typically covers some 12,600 nautical miles, according to an article in Canada's *Globe and Mail*, while the trip via the Northwest Passage would be shortened to 7,900 nautical miles. The risk is that the environmental damage from any accidents, such as an oil spill in the Arctic Sea, could last for decades if not longer in this frigid environment.[51]

At the other end of the earth, the 2-kilometer thick Antarctic ice sheet covers a continent about twice the size of Australia and contains 70 percent of the world's fresh water. Ice shelves that extend from the continent into the surrounding seas are beginning to break up at an alarming pace.[52]

The ice shelves surrounding Antarctica are formed by the flow of glaciers off the continent to lower levels in the surrounding sea. This flow of ice, fed by the continuous formation of new ice on land and culminating in the breakup of the shelves on the outer fringe and the calving of icebergs, is not new. What is new is the pace of this process. When Larsen A, a huge ice shelf on the east coast of the Antarctic Peninsula, broke up in 1995, it was a signal that all was not well in the region. Then in 2000, a huge iceberg nearly the size of Connecticut—11,000 square kilometers, or 4,250 square miles—broke off the Ross Ice Shelf.[53]

After Larsen A broke up, it was only a matter of time, given the rise in temperature in the region, before Larsen B would do the same. In November 2001, an alert went out to the scientific community from a researcher at the Instituto Antártico Argentino, who noted the unusually warm spring temperature and the 20-percent acceleration in the flow of the ice shelf. So when the northern part of the Larsen B ice shelf collapsed into the sea in March 2002, it was not a total surprise. At about the same time, a huge chunk of ice broke off the Thwaite Glacier. Covering 5,500 square kilometers, this iceberg was the size of Rhode Island.[54]

Even veteran ice watchers are amazed at how quickly the disintegration is occurring. "The speed of it is staggering," said Dr. David Vaughan, a glaciologist at the British Antarctic Survey, which has been monitoring the Larsen Ice Shelf closely. Along the Antarctic Peninsula, in the vicinity of the Larsen Ice Shelf, the average temperature has risen 2.5 degrees Celsius over the last five decades. Higher temperatures lead to ice melting on the surface of the ice shelves. Scientists theorize that as the melted water on the surface penetrates fractures, it weakens the ice, making it vulnerable to further fracturing.[55]

When ice shelves already in the water break off from the continental ice mass, this does not have much direct effect on sea level per se. But without the ice shelves to impede the flow of glacial ice, typically moving 400–900 meters a year, the flow of ice from the continent could accelerate, leading to a thinning of the ice sheet on the edges of the Antarctic continent. If this were to happen, sea level would rise. Dr. Neal Young of the Antarctic Cooperative Research Centre at the University of Tasmania in Australia notes that after Larsen A broke off, the upstream rate of glacial flow at least doubled.[56]

The accelerated melting of ice, which is consistent with the accelerating rise in temperature that has occurred since 1980, is of great concern in low-lying regions of coastal countries and low-lying island countries. Perhaps the most easily measured effect of rising sea level is the inundation of coastal areas. Donald F. Boesch, with the University of Maryland's Center for Environmental Sciences, estimates that for each 1-meter rise in sea level, the shoreline will retreat by an average 1,500 meters, or nearly a mile.[57]

In 2000, the World Bank published a map showing that a 1-meter rise in sea level would inundate half of Bangladesh's riceland. With a rise in sea level of up to 1 meter forecast for this century, tens of millions of Bangladeshis would be forced to migrate. In a country with 142 million people—already one of the most densely populated on earth—this would be a traumatic experience. Rice-growing river floodplains in other Asian countries would also be affected, including India, Thailand, Viet Nam, Indonesia, and China. With a 1-meter rise in sea level, more than a third of Shanghai, a city of 13 million people, would be under water.[58]

Such a rise would cost the United States 36,000 square kilometers (14,000 square miles) of land, most of it in the middle Atlantic and Mississippi Gulf states. With a 50-year storm surge, large portions of Lower Manhattan and the

National Mall in the center of Washington, D.C., would be flooded with seawater.[59]

While public attention focuses on the effect of ice melting on sea level rise, the thermal expansion of the oceans as a result of rising temperature is also raising sea level. At present, scientists estimate the relative contributions of ice melting and thermal expansion to sea level rise to be about the same. Together, the two are raising sea level at a measurable rate. It has become an indicator to watch—a trend that could force a human migration of unimaginable dimensions. It also raises questions about responsibility to future generations that humanity has never before faced.[60]

More Destructive Storms

Rising seas are not the only threat that comes with elevated global temperatures. Higher surface water temperatures in the tropical oceans mean more energy radiating into the atmosphere to drive tropical storm systems, leading to more frequent and more destructive storms. The combination of rising seas, more powerful storms, and stronger storm surges can be devastating.[61]

In the fall of 1998, Hurricane Mitch—one of the most powerful storms ever to come out of the Atlantic, with winds approaching 200 miles per hour—hit the east coast of Central America. As atmospheric conditions stalled the normal northward progression of the storm, some 2 meters of rain were dumped on parts of Honduras and Nicaragua within a few days. The deluge collapsed homes, factories, and schools, leaving them in ruins. It destroyed roads and bridges. Seventy percent of the crops and much of the topsoil in Honduras were washed away—topsoil that had accumulated over long stretches of geological time. Huge mudslides destroyed villages, sometimes burying local populations.[62]

The storm left 11,000 dead. Thousands more were never found. The basic infrastructure—the roads and bridges in Honduras and Nicaragua—was largely destroyed. President Flores of Honduras summed it up this way: "Overall, what was destroyed over several days took us 50 years to build." The damage from this storm, exceeding the annual gross national product of the two countries, set their economic development back by 20 years.[63]

In 2004, Japan experienced a record 10 typhoons (hurricanes) that collectively caused \$10 billion worth of losses. During the same season, the state of Florida was hit by 4 of the 10 most costly hurricanes in U.S. history. These 4 hurricanes together generated insurance claims of \$22 billion.[64]

A year later, these storms were dwarfed when Hurricane Katrina came onshore in the U.S. Gulf region with a storm surge of more than 20 feet that totally destroyed many coastal towns. The storm also flooded New Orleans, leaving much of it uninhabitable. Altogether the storm generated hundreds of thousands of refugees from Alabama, Mississippi, and Louisiana. This powerful storm, fueled by higher temperatures of surface waters in the Gulf, left in its wake a bill estimated early on at \$200 billion. Since it will take years for the region to fully recover, the cost could climb even higher.[65]

Against this backdrop, insurance companies and reinsurance companies find it difficult to calculate a safe level of premiums, since the historical record traditionally used to calculate insurance fees is no longer a guide to the future. For example, the number of major flood disasters worldwide has grown during each of the last several decades, increasing from 6 major floods in the 1950s and 1960s to 8 in the 1970s, 18 in the 1980s, and 26 in the 1990s.[66]

The insurers are convinced that with higher temperatures and more energy driving storm systems, future losses will be even greater. They are concerned about whether the industry can remain solvent under this onslaught of growing damages. So, too, is Moody's Investors Service, which in 2002 downgraded the creditworthiness of several of the world's leading reinsurance companies. Since then, one of these firms—Munich Re—reported that 2004 was a record year of claims for the insurance industry worldwide even after adjusting for inflation.[67]

Thomas Loster, a Munich Re climate expert, said at the end of 2004: "As in 2002 and 2003, the overall balance of natural catastrophes is again clearly dominated by weather-related disasters, many of them exceptional and extreme.…We need to stop this dangerous experiment humankind is conducting on the Earth's atmosphere." The insurance industry is particularly concerned about new climate-related risks that may be emerging, such as Hurricane Catarina, which developed in 2004 in the South Atlantic, where water temperatures are not usually high enough to generate a hurricane. Whether Catarina, which came onshore in southern Brazil, is an anomalous event or the beginning of a disturbing new trend remains to be seen.[68]

Munich Re has published a list of storms with insured losses of $1 billion or more. The first such natural disaster came in 1983, when Hurricane Alicia struck the United States, racking up $1.5 billion in insured losses. Of the 49 natural catastrophes with $1 billion or more of insured losses recorded through the end of 2004, 3 were earthquakes, including the devastating 2004 Asian tsunami; the other 46 were weather-related—storms, floods, hurricanes, or wildfires. During the 1980s, there were 3 such events; during the 1990s, there were 26; and during the first half of the current decade, 2000 through 2004, there were 17.[69]

Prior to Hurricane Katrina, the two largest events in terms of total damage were Hurricane Andrew in 1992, which took down 60,000 homes and racked up $30 billion worth of damage, and the flooding of China's Yangtze river basin in 1998, which also cost an estimated $30 billion, a sum comparable to the value of China's rice harvest. Part of the growing damage toll is due to greater urban and industrial development in coastal areas and river floodplains. But part is due to more frequent, more destructive storms.[70]

The regions most vulnerable to more powerful storms currently are the Atlantic and Gulf Coasts of the United States and the Caribbean countries. In Asia, it is East and Southeast Asia, including the Philippines, Taiwan, Japan, China, and Viet Nam, that are likely to bear the brunt of the powerful storms crossing the Pacific. Further west, in the Bay of Bengal, Bangladesh and the east coast of India are particularly vulnerable.

Western Europe, traditionally experiencing a heavily damaging winter storm perhaps once in a century, had its first winter storm to exceed $1 billion in 1987—one that wreaked $3.7 billion in destruction, $3.1 billion of which was covered by insurance. Since then, it has had eight winter storms with insured losses ranging from $1.3 billion to $5.9 billion.[71]

Andrew Dlugolecki, a senior officer at the CGMU Insurance Group, the largest insurance company in the United Kingdom, notes that damage from atmospherically related events has increased by roughly 10 percent a year. "If such an increase were to continue indefinitely," he notes, "by 2065 storm damage would exceed the gross world product. The world obviously would face bankruptcy long before then." In the real world, few growth trends continue at a fixed rate for several decades, but Dlugolecki's basic point is that climate change can be destructive, disruptive, and very costly.[72]

Subsidizing Climate Change

At a time of mounting public concern about climate change driven by the burning of fossil fuels, the world fossil fuel industry is still being subsidized by taxpayers at more than $210 billion per year. Fossil fuel subsidies belong to another age, a time when development of the oil and coal industries was seen as a key to economic progress—not as a threat to our twenty-first century civilization. Once in place, subsidies lead to special interest lobbies that fight tooth and nail against eliminating them, even those that were not appropriate in the first place.[73]

In the United States, oil and gas companies are now perhaps the most powerful lobbyists in Washington. Between 1990 and 2004, they amassed $181 million in campaign contributions in an effort to protect special tax deductions worth billions. In testimony before the House Ways and Means Committee in 1999, Donald Lubick, U.S. Treasury Assistant Secretary for Tax Policy, said in reference to oil and gas companies: "This is an industry that probably has a larger tax incentive relative to its size than any other industry in the country." That such profitable investments are possible is a measure of the corruption of the U.S. political system, particularly the capacity of those with money to shape the economy to their advantage.[74]

Subsidies permeate and distort every corner of the global economy. Germany's coal mining subsidy was initially justified in part as a job protection measure, for example. At its peak, the government was subsidizing the industry to the tune of nearly $90,000 per year for each worker. In purely economic terms, it would have made more sense to close the mines and pay miners not to work.[75]

Many subsidies are largely hidden from taxpayers. This is especially true of the fossil fuel industry, whose subsidies include such things as a depletion allowance for oil pumping in the United States. Even more dramatic are the routine U.S. military expenditures to protect access to Middle Eastern oil, which were calculated by analysts at the Rand Corporation before the most recent Iraq war to fall between $30 billion and $60 billion a year, while the oil imported from the region was worth only $20 billion.[76]

A 2001 study by Redefining Progress shows U.S. taxpayers subsidizing automobile use at $257 billion a year, or roughly $2,000 per taxpayer. In addition to subsidizing carbon emissions, this also means that taxpayers who do not own automobiles, including those too poor to afford them, are subsidizing those who do.[77]

One of the bright spots about this subsidization of fossil fuels is that it provides a reservoir of tax deductions that can be diverted to climate-benign, renewable sources of energy, such as wind, solar, and geothermal energy. Shifting these subsidies from fossil fuels to the development of renewable sources would be a win-win situation, as described in Chapter 12. To subsidize the use of fossil fuels is to subsidize crop-withering heat waves, melting ice, rising seas, and more destructive storms. Perhaps it is time for the world's taxpayers to ask if this is how they want their hard-earned money to be spent.