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Rising Temperatures, Melting Ice, and Food Security

On August 5th, 2010, the Petermann Glacier on the northwest coast of Greenland gave birth to an iceberg that covered 97 square miles. Four times the size of Manhattan, in late 2010 this "ice island" is floating between Greenland and Canada, drifting slowly southward with the prevailing currents. Since it is up to half the height of the Empire State Building in thickness, it could take years for it to melt, break up, and eventually disappear.[1]

News of this massive ice break focused attention on the Greenland ice sheet once more. Scientists have been reporting for some years that it was melting at an accelerating rate. In 2007, Robert Corell, chairman of the Arctic Climate Impact Assessment, reported from Greenland that "we have seen a massive acceleration of the speed with which these glaciers are moving into the sea." He noted that ice was moving at over 6 feet an hour on a front 3 miles long and 1 mile deep.[2]

In August 2010, Richard Bates, a member of a British-led expedition monitoring the Greenland ice sheet, said, "This year marks yet another record-breaking melt year in Greenland; temperatures and melt across the entire ice sheet have exceeded those . . . of historical records."[3]

Greenland was not alone in experiencing extremes in 2010. New high-temperature records were set in 18 coun-

tries. The number of record highs was itself a record, topping the previous total of 15 set in 2007. When a site in south central Pakistan hit 128 degrees Fahrenheit on May 26th, it set not only a new national record, but also a new all-time high for Asia.[4]

Within the United States, numerous cities on the East Coast suffered through the hottest June to August on record, including New York, Philadelphia, and Washington. After a relatively cool summer in Los Angeles, the temperature there on September 27 reached an all-time high of 113 degrees before the official thermometer broke. At a nearby site, however, the thermometer survived to register 119 degrees, a record for the region. What U.S. climate data show us is that as the earth has warmed, record highs are now twice as likely as record lows.[5]

The pattern of more-intense heat waves, more-powerful storms, and more-destructive flooding is consistent with what climate models project will happen as the earth's temperature rises. The worst heat wave in Russian history and the worst flooding in Pakistan's history are the kind of extreme events we can expect to see more of if we continue with business as usual. James Hansen, the U.S. government's leading climate scientist, asks, "Would these events have occurred if atmospheric carbon dioxide had remained at its pre-industrial level of 280 ppm [parts per million]?" The answer, he says, is "almost certainly not."[6]

As atmospheric carbon dioxide levels rise, we can expect even higher temperatures in the future. The earth's average temperature has risen in each of the last four decades, with the increase in the last decade being the largest. As a general matter, temperature rise is projected to be greater in the higher latitudes than in equatorial regions, greater over land than over the oceans, and greater in the interior of continents than in coastal regions.[7]

As the planet heats up, climate patterns shift. Overall, higher temperature means more evaporation and therefore more precipitation. Some parts of the earth will get wetter, other parts dryer. Monsoon patterns will change. Wetter regions will be concentrated in the higher latitudes—including Canada, northern Europe, and Russia—and in Southeast Asia. Places at particular risk of drying out include the Mediterranean region, Australia, and the U.S. Southwest.[8]

Climate instability is becoming the new norm. The time when we could use climate trends of the recent past as a guide to future climate conditions is now history. We are moving into an age of unpredictability.

The effects of high temperatures on food security are scary. Agriculture as it exists today has evolved over 11,000 years of rather remarkable climate stability. As a result, world agriculture has evolved to maximize productivity within this climatic regime. With the earth's climate changing, agriculture will increasingly be out of sync with the climate system that shaped it.

When temperatures soar during the growing season, grain yields fall. Crop ecologists use a rule of thumb that for each 1-degree-Celsius rise in temperature above the optimum during the growing season, we can expect a 10-percent decline in grain yields.[9]

Among other things, temperature affects photosynthesis. 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 68 degrees Fahrenheit. The rate of photosynthesis then plateaus until the temperature hits 95 degrees, whereupon it begins to decline. At 104 degrees, photosynthesis ceases entirely.[10]

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 to heat stress. 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 to nearly zero at 104 degrees Fahrenheit, leading to crop failure.[11]

Heat waves clearly can decimate harvests. Other effects of higher temperatures on our food supply are less obvious but no less serious. Rising temperatures are already melting ice caps and glaciers around the globe. The massive West Antarctic and Greenland ice sheets are both melting. The Greenland ice cap is melting so fast in places that it is triggering minor earthquakes as huge chunks of ice weighing millions of tons break off and slide into the sea.[12]

The breakup of ice in West Antarctica is also gaining momentum. One of the first signals that this ice sheet was breaking up came in 1995 when Larsen A—a huge shelf on the Antarctic Peninsula—collapsed. Then in March 2002 the Larsen B ice shelf collapsed into the sea. At about the same time, over 2,000 square miles of ice broke off the Thwaites Glacier. And in January 2010 an area larger than Rhode Island broke off the nearby Ronne-Filchner ice shelf. If the West Antarctic ice sheet were to melt entirely, sea level would rise by 16 feet.[13]

Temperatures are rising much faster in the Arctic than elsewhere. Winter temperatures in the Arctic, including

Alaska, western Canada, and eastern Russia, have climbed by 4–7 degrees Fahrenheit over the last half-century. This record rise in temperature in the Arctic region could lead to changes in climate patterns that will affect the entire planet.[14]

Sea ice in the Arctic Ocean has been shrinking for the last few decades. Some scientists now think the Arctic Ocean could be free of ice during the summer by 2015—less than five years from now. This worries climate scientists because of the albedo effect. When incoming sunlight strikes the ice in the Arctic Ocean, up to 70 percent is reflected back into space and as little as 30 percent is absorbed as heat. As the Arctic sea ice melts, however, and the incoming sunlight hits the much darker open water, only 6 percent is reflected back into space and 94 percent is converted into heat. This creates a positive feedback—a situation where a trend, once under way, feeds on itself.[15]

If ice disappears entirely in summer and is reduced in winter, the Arctic region will heat up even more, ensuring that the Greenland ice sheet will melt even faster. Recent studies indicate that a combination of melting ice sheets and glaciers, plus the thermal expansion of the ocean as it warms, could raise sea level by up to 6 feet during this century, up from a 6-inch rise during the last century.[16]

Even a 3-foot rise in sea level would sharply reduce the rice harvest in Asia, home to over half of the world's people. It would inundate half the riceland in Bangladesh, a country of 164 million people, and would submerge part of the Mekong Delta, a region that produces half of Viet Nam's rice. Viet Nam, second only to Thailand as a rice exporter, could lose its exportable surplus of rice. This would leave the 20 or so countries that import rice from Viet Nam looking elsewhere.[17]

In addition to the Gangetic Delta in Bangladesh and the Mekong Delta in Viet Nam, numerous other rice-

growing river deltas in Asia would be submerged in varying degrees by a 3-foot rise in sea level. It is not intuitively obvious that ice melting on a large island in the far North Atlantic could shrink the rice harvest in Asia, a region that grows 90 percent of the world's rice.[18]

While the ice sheets are melting, so too are mountain glaciers—nature's freshwater reservoirs. The snow and ice masses in the world's mountain ranges and the water they store are taken for granted simply because they have been there since before agriculture began. Now that is changing. If we continue raising the earth's temperature, we risk losing the "reservoirs in the sky" on which so many farmers and cities depend.

Americans need not go far from home to see massive glacier melting. In 1910, when Glacier National Park in western Montana was created, it had some 150 glaciers. In recent decades, these glaciers have been disappearing. By the end of 2009, only 27 were left. In April 2010 park officials announced that 2 more had melted, leaving only 25. It appears to be only a matter of time until all the park's glaciers are gone.[19]

Other landmarks, such as the glaciers on Mount Kilimanjaro in East Africa, are also melting quickly. Between 1912 and 2007, Kilimanjaro's glaciers shrank 85 percent. It is too late to save this landmark. Like the glaciers in Glacier National Park, those on Kilimanjaro may soon be relegated to photographs in museums.[20]

The World Glacier Monitoring Service has reported the nineteenth consecutive year of shrinking mountain glaciers. Glaciers are melting in all of the world's major mountain ranges, including the Andes, the Rockies, the Alps, the Himalayas, and the Tibetan Plateau.[21]

Ice melt from mountain glaciers in the Himalayas and on the Tibetan Plateau helps sustain the major rivers of Asia during the dry season, when irrigation water needs are greatest. In the Indus, Ganges, Yellow, and Yangtze

River basins, where irrigated agriculture depends heavily on the rivers, the loss of any dry-season flow is bad news for farmers.[22]

These melting glaciers coupled with the depletion of aquifers present the most massive threat to food security the world has ever faced. China is the world's leading producer of wheat. India is number two. (The United States is number three.) With rice, China and India totally dominate the world harvest.[23]

In India, the giant Gangotri Glacier, which helps keep the Ganges River flowing during the dry season, is retreating. The Ganges River is not only by far the largest source of surface water irrigation in India, it is also a source of water for the 407 million people living in the Gangetic basin.[24]

Yao Tandong, a leading Chinese glaciologist, reports that glaciers on the Tibetan Plateau in western China are now melting at an accelerating rate. Many smaller glaciers have already disappeared. Yao believes that two thirds of these glaciers could be gone by 2060. If this melting of glaciers continues, Yao says it "will eventually lead to an ecological catastrophe."[25]

The Yellow River basin is home to 147 million people; their fate is closely tied to the river because of low rainfall in the northern half of China. The Yangtze is by far the country's largest river, helping to produce half or more of its 130-million-ton rice harvest. The Yangtze basin is home to 369 million people—more than the entire population of the United States.[26]

Thus the number of people affected by the melting and eventual disappearance of glaciers will be huge. The prospect of shrinking dry-season river flows is unfolding against a startling demographic backdrop: by 2030, India is projected to add 270 million people to its population of 1.2 billion and China is due to add 108 million to its 1.3 billion. While farmers in China and India are already los-

ing irrigation water as overpumping depletes aquifers, they are also facing a reduction of river water for irrigation.[27]

In a world where grain prices have recently climbed to record highs, any disruption of the wheat or rice harvests due to water shortages in India or China will raise their grain imports, driving up food prices. In each of these countries, food prices will likely rise as glaciers disappear and dry-season flows diminish. In India, where just over 40 percent of all children under five years of age are underweight and undernourished, hunger will intensify and child mortality will likely climb.[28]

The depletion of glaciers in the early stage can expand river flows for a time, thus potentially increasing the water available for irrigation. Like the depletion of aquifers, the melting of glaciers can artificially inflate food production for a short period. At some point, however, as the glaciers shrink and the smaller ones disappear entirely, so does the water available for irrigation.[29]

In South America, some 22 percent of Peru's glacial endowment, which feeds the many rivers that supply water to farmers and cities in the arid coastal regions, has disappeared. Ohio State University glaciologist Lonnie Thompson reported in 2007 that the Quelccaya Glacier in southern Peru, which had been retreating by 20 feet per year in the 1960s, was retreating by 200 feet annually. In an interview with *Science News* in early 2009 he said, "It is now retreating up the mountainside by about 18 inches a day, which means you can almost sit there and watch it lose ground."[30]

As Peru's glaciers shrink, the water flow from the mountains to the country's arid coastal region, where 60 percent of the people live, will decline during the dry season. This region includes Lima, which, with nearly 9 million inhabitants, is the world's second largest desert city, after Cairo. Given the coming decline in its water supply, a U.N. study refers to Lima as "a crisis waiting to happen."[31]

Bolivia is also fast losing the glaciers whose ice melt supplies its farmers and cities with water. Between 1975 and 2006, the area of its glaciers shrank by nearly half. Bolivia's famed Chacaltaya Glacier, once the site of the world's highest ski resort, disappeared in 2009.[32]

For the 53 million people living in Peru, Bolivia, and Ecuador, the loss of their mountain glaciers and dry-season river flow threatens their food security and political stability. Not only do farmers in the region produce much of their wheat and potatoes with the river water from these disappearing glaciers, but well over half the region's electricity supply comes from hydroelectric sources. Currently, few countries are being affected by melting mountain glaciers as much as these Andean societies.[33]

In many of the world's agricultural regions, snow is the leading source of irrigation and drinking water. In the southwestern United States, for instance, the Colorado River—the region's 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 mountain range to supply irrigation water to the Central Valley, the country's fruit and vegetable basket.[34]

A preliminary analysis of rising temperature effects on three major river systems in the western United States—the Columbia, the Sacramento, and the Colorado—indicates that the winter snow pack in the mountains feeding them will be reduced dramatically and that winter rainfall and flooding will increase. With a business-as-usual energy policy, global climate models project a 70-percent reduction in the 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, shows progressively heavier

harvest losses as the snow pack shrinks, reducing irrigation water flows.[35]

Agriculture in the Central Asian countries of Afghanistan, Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, and Uzbekistan depends heavily on snowmelt from the Hindu Kush, Pamir, and Tien Shan Mountain ranges for irrigation water. And nearby Iran gets much of its water from the snowmelt in the 5,700-meter-high Alborz Mountains between Tehran and the Caspian Sea.[36]

The continuing loss of mountain glaciers and the reduced runoff that comes from that loss could create unprecedented water shortages and political instability in some of the world's more densely populated countries. For China, a country already struggling to contain food price inflation, there may well be spreading social unrest if food supplies tighten.[37]

For Americans, the melting of the glaciers on the Tibetan Plateau would appear to be China's problem. It is. But it is also everyone else's problem. For U.S. consumers, this melting poses a nightmare scenario. If China enters the world market for massive quantities of grain, as it has already done for soybeans over the last decade, it will necessarily come to the United States—far and away the leading grain exporter. The prospect of 1.3 billion Chinese with rapidly rising incomes competing with American consumers for the U.S. grain harvest, and thus driving up food prices, is not an attractive one.[38]

In the 1970s, when tight world food supplies were generating unacceptable food price inflation in the United States, the government restricted grain exports. This, however, may not be an option where China is concerned. Each month when the Treasury Department auctions off securities to cover the U.S. fiscal deficit, China is one of the big buyers. Now holding close to $900 billion of U.S. debt, China has become the banker for the United States. Like it or not, American consumers will be sharing the

U.S. grain harvest with Chinese consumers. The idea that shrinking glaciers on the Tibetan Plateau could one day drive up food prices at U.S. supermarket checkout counters is yet another sign of the complexity of our world.[39]

Ironically, the two countries that are planning to build most of the new coal-fired power plants, China and India, are precisely the ones whose food security is most massively threatened by the carbon emitted from burning coal. It is now in their interest to try and save their mountain glaciers by quickly shifting energy investment from coal-fired power plants into energy efficiency, wind farms, solar thermal power plants, and geothermal power plants.[40]

We know from studying earlier civilizations that declined and collapsed that shrinking harvests often were responsible. For the Sumerians, it was rising salt concentrations in the soil that lowered wheat and barley yields and eventually brought down this remarkable early civilization. For us, it is rising carbon dioxide concentrations in the atmosphere that are raising the global temperature, which ultimately could shrink grain harvests and bring down our global civilization.[41]

Data, endnotes, and additional resources can be found on Earth Policy's Web site, at www.earth-policy.org.