The Big Thaw

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It's no surprise that a warming climate is melting the world's glaciers and polar ice. But no one expected it to happen this fast.

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Even in better times, the Chacaltaya ski area was no competition for Aspen. Set in a bleak valley high in the Andes mountains of Bolivia, it offered a half-mile (one kilometer) swoop downhill, a precarious ride back up on a rope tow, and coca-leaf tea for altitude headaches. At 17,250 feet (5,260 meters), after all, Chacaltaya was the highest ski area in the world. "It gave us a lot of glory," says Walter Laguna, the president of Bolivia's mountain club. "We organized South American championships—with Chile, with Argentina, with Colombia."

The glory days are over. Skiing at this improbable spot depended on a small glacier that made a passable ski run when Bolivia's wet season dusted it with snow. The glacier was already shrinking when the ski area opened in 1939. But in the past decade, it's gone into a death spiral.

By last year all that remained were three patches of gritty ice, the largest just a couple of hundred yards (200 meters) across. The rope tow traversed boulder fields. Laguna insists that skiing will go on. Perhaps the club can make artificial snow, he says; perhaps it can haul in slabs of ice to mend the glacier. But in the long run, he knows, Chacaltaya is history. "The process is irreversible. Global warming will continue."

From the high mountains to the vast polar ice sheets, the world is losing its ice faster than anyone thought possible. Even scientists who had monitored Chacaltaya since 1991 thought it would hold out for a few more years. It's no surprise that glaciers are melting as emissions from cars and industry warm the climate. But lately, the ice loss has outstripped the upward creep of global temperatures.

Scientists are finding that glaciers and ice sheets are surprisingly touchy. Instead of melting steadily, like an ice cube on a summer day, they are prone to feedbacks, when melting begets more melting and the ice shrinks precipitously. At Chacaltaya, for instance, the shrinking glacier exposed dark rocks, which sped up its demise by soaking up heat from the sun. Other feedbacks are shriveling bigger mountain glaciers ahead of schedule and sending polar ice sheets slipping into the ocean.

Most glaciers in the Alps could be gone by the end of the century, Glacier National Park's namesake ice by 2030. The small glaciers sprinkled through the Andes and Himalaya have a few more decades at best. And the prognosis for the massive ice sheets covering Greenland and Antarctica? No one knows, if only because the turn for the worse has been so sudden. Eric Rignot, a scientist at NASA's Jet Propulsion Laboratory who has measured a doubling in ice loss from Greenland over the past decade, says: "We see things today that five years ago would have seemed completely impossible, extravagant, exaggerated."

The fate of many mountain glaciers is already sealed. To keep skiing alive in Bolivia, Walter Laguna will need to find a bigger, higher ice field. And the millions of people in countries like Bolivia, Peru, and India who now depend on meltwater from mountain glaciers for irrigation, drinking, and hydropower could be left high and dry. Meanwhile, if global warming continues unabated, the coasts could drown. If vulnerable parts of the ice that blankets Greenland and Antarctica succumb, rising seas could flood hundreds of thousands of square miles—much of Florida, Bangladesh, the Netherlands—and displace tens of millions of people.

The temperature threshold for drastic sea-level rise is near, but many scientists think we still have time to stop short of it, by sharply cutting back consumption of climate-warming coal, oil, and gas. Few doubt, however, that another 50 years of business as usual will take us beyond a point of no return.

Ancient coral heads, white and dead, record an earlier time when the climate warmed and the seas rose. Found just inland in the Florida Keys, Bermuda, and the Bahamas, they date from roughly 130,000 years ago, before the last ice age. These corals grew just below the sea surface, and are now marooned well above it. When they flourished, sea level must have been 15 to 20 feet (five to six meters) higher—which means that much of the water now in Greenland's ice was sloshing in the oceans.

All it took to release that water was a few degrees of warming. Climate back then had a different driver: not fossil-fuel emissions but changes in Earth's tilt in space and its path around the sun, which warmed summers in the far North by three to five degrees Celsius (5° to 9°F) compared with today. At the rate the Arctic is now warming, those temperatures could be back soon—"by mid-century, no problem," says Jonathan Overpeck of the University of Arizona, who has studied the ancient climate. "There's just unbelievable warming in the Arctic. It's going much faster than anyone thought it could or would."

Computer models that forecast how ice sheets will react to the warming tend to predict a sluggish response—a few thousand years for them to melt, shrink, and catch up to the reality of a warmer world. If the models are right, rising seas are a distant threat. Yet what is happening on the Greenland ice sheet is anything but leisurely. For the past 15 years, Konrad Steffen of the University of Colorado at Boulder has spent each spring monitoring the ice from a camp deep in the interior. Back again in the coastal village of Ilulissat last summer, the Swiss-born climate researcher, lean and weathered from wind and glacial glare, sits with colleagues in a waterfront hotel, waiting out fog that has grounded their helicopter. “Things are changing,” he says. “We see it all over.”

Offshore, flotillas of icebergs drift silvery in the half-light—tangible evidence of the change. Their voyage began nearby in a deep fjord, where a glacier called Jakobshavn Isbræ flows to the sea. Ice seems rock hard when you crunch an ice cube or slip on a frozen puddle. But when piled in a great mass, ice oozes like slow, cold taffy. On Greenland, it flows outward from the heart of the ice sheet, a dome of ice the size of the Gulf of Mexico, and either peters out on land or follows fast-flowing ice streams all the way to the ocean. Four miles (six kilometers) wide and several thousand feet thick, Jakobshavn is an icy Amazon, disgorging more ice than any other Greenland glacier.

Jakobshavn is flowing ever faster. In the past decade it doubled its speed, to roughly 120 feet (37 meters) a day. By now it discharges 11 cubic miles (45 cubic kilometers) of ice each year, jamming the fjord with fresh icebergs. The pace is picking up elsewhere around Greenland. Last year Eric Rignot reported satellite radar measurements showing that most glaciers draining the southern half of the Greenland ice sheet have accelerated, some even more dramatically than Jakobshavn. He calculated that Greenland lost a total of 54 cubic miles (225 cubic kilometers) of ice in 2005, more than twice as much as ten years ago—and more than some scientists were prepared to believe. Two of the outlet glaciers have since slowed down. But other satellites detected a minuscule weakening of Greenland’s gravity, confirming that it is shedding ice at a rate of tens of cubic miles a year. Says Waleed Abdalati, a NASA scientist who oversees research on Greenland and Antarctica, “The ice sheet is starting to stir.”

Just as Jakobshavn accelerated, its tongue—the glacier’s seaward end, floating on the waters of the fjord—began to shatter and retreat. Since 2000, the tongue has receded by four miles (six kilometers), adding to the clutter of icebergs in the fjord. Many of the other Greenland glaciers racing to the sea have also lost part or all of their tongues, which may explain the speedup. “Floating ice acts as a buttress,” explains Abdalati. “It holds back the ice behind it, so that when it melts, it sort of uncorks the glacier.”

Greenland’s weather has warmed palpably. Winter temperatures at Steffen’s ice camp have risen about five degrees Celsius (9°F) since 1993. In the past, researchers riding snowmobiles to outlying instrument stations could still count on firm snow as late as May; last year they got stuck in slush. For the past two years Ilulissat—well above the Arctic Circle, a place where street signs mark dogsled crossings—has had long winter thaws. “It was supposed to be minus 20 (-29°C),” says Steffen, “and instead it was raining.”

Offshore, the middle depths of the Atlantic have warmed as well, by several tenths of a degree—enough to undermine an ice tongue that is also melting from above. Eventually all of Greenland’s floating ice could disintegrate. At that point the ice streams may stop accelerating. Then again, they may not, Steffen says. The weight of Greenland’s ice sheet has forced its bedrock down into a vast basin, much of it below sea level. As the glaciers retreat inland, the ocean may follow, prying them off their bed in a runaway process of collapse.

Right now Greenland is no threat to beachfront property. Steven Nerem of the University of Colorado at Boulder, who monitors sea level by satellite, says the oceans have been rising an eighth of an inch (0.3 centimeter) a year. At that rate the sea would go up a foot (0.3 meters) by 2100, roughly what a United Nations panel on climate change predicted earlier this year. “But that’s nothing compared to what we expect if Greenland really starts to go,” Nerem says.

The latest signs from Greenland have persuaded many ice researchers that sea level could rise three feet (one meter) by 2100. Rignot, who has measured the rush of glaciers to the sea, says even that figure may turn out to be an underestimate. Greenland, he notes, could ultimately add ten feet (three meters) to global sea level, “and if this happens in the next hundred years instead of the next several hundred years, that’s a very big deal.”

The fog has lifted, though a drizzle lingers. The helicopter has unloaded Steffen’s team onto the pitted, eroding ice sheet, about five miles (eight kilometers) in from the edge. This is the ice sheet’s ablation zone, its warm, low margin, where ice from the interior comes to die. It’s August, the height of the melting season. Washbasin-size pools of meltwater dapple the surface, and blue streams thread across the icescape. All that water—already a loss to the ice sheet—could be causing the ice to dwindle even faster. The first hints of this feedback came ten years ago at Steffen’s springtime ice camp. NASA scientist Jay Zwally set out some GPS beacons to measure how fast the ice was creeping outward from the heart of Greenland to the ablation zone. Within a couple of years an odd correlation had turned up: the more the surface melted, the faster the great pile of ice moved.

At first the effect was subtle: For a few days in high summer, the ice sped up by 10 percent over its usual pace of about a foot a day. But year by year, as the climate warmed and the melting season lengthened, the lurching increased. Zwally and Steffen proposed that the cause was meltwater pooling at the base of the ice and lubricating its contact with the bedrock. Like a car skidding on a wet road, they suggested, the ice was hydroplaning across its bed.

Somehow, water must be percolating all the way from the surface of the ice down to its base. Here and there in the ablation zone, summer melt collects in azure lakes hundreds of yards across. Sometimes, a lake vanishes from one day to the next down some invisible drain. Not far from where Steffen's helicopter touched down, a cleft in the ice, called a moulin, swallows a foaming torrent of meltwater.

Steffen, glaciologist Nicolas Cullen, and JPL engineer Alberto Behar are here to trace the plunging water. Does it plummet straight to the bottom down a chute? Does it cascade in steps? The easier the route down, the faster the ice may slide in coming years. Behar unpacks a video camera protected in a torpedo-shaped steel housing. Before winching the camera down the moulin, the scientists rope themselves to anchors screwed into the ice and crane over the edge. The waterfall booms in the blackness, but as his eyes adjust, Steffen can make out the dimensions of the chasm. "It's the biggest moulin I've seen so far," he yells over the din. "I think it's as big as a subway station."

Lowered into the depths at the end of a fiber-optic cable, the camera drops about 350 feet (110 meters), then comes to rest. In a tent set back from the drop-off, a screen shows the view from the camera: It is perched on an icy ledge, with grit-laden water rushing past. No amount of yanking on the cable frees the camera to descend any farther. Maybe it is near the base of the ice sheet—the grit could be a clue—maybe not. The scientists would like to come back for another try with a lightweight camera that might be swept along with the current.

The ice sheet's deep plumbing is still mysterious, but its effects are clearer than ever. In recent summers the ice briefly tripled its normal speed, racing faster than ever to destruction. Look at a map, and it's easy to see why the Greenland ice sheet is so vulnerable: Its southern end is no farther north than ice-free Anchorage or Stockholm. Greenland's ice is a relic of the last ice age, surviving only because it is massive enough to make its own climate. The island's brilliant, perpetually snow-covered interior reflects light and heat. Its elevation adds to the chill, and its bulk fends off warm weather systems from farther south. As the ice sheet shrinks, all these defenses will weaken.

The bigger ice mass at the other end of the globe seems less fragile. Except for the Antarctic Peninsula, which juts past the Antarctic Circle, Antarctica is safely deep-frozen. Global warming may even be causing parts of the ice sheet to thicken, because warmer air ferries more moisture, leading to heavier snowfall. But around one remote Antarctic sea, scientists are picking up a disturbing echo of what is happening in Greenland.

The glaciers that flow into the Amundsen Sea carry ice from the heart of the West Antarctic ice sheet, the smaller of the southern continent's two ice masses. Like Greenland's ice, West Antarctica's rests on a bed that is largely below sea level. And its outlet glaciers too are stirring.

One of them, the Pine Island Glacier, a mammoth ice stream more than 20 miles (30 kilometers) wide and half a mile (one kilometer) thick, has sped up by a third since the 1970s. Another, Thwaites Glacier, has widened, gathering ever more ice into the seaward-flowing mass. There's little agreement about how much ice West Antarctica is losing each year. But the loss could grow, eventually adding five feet (two meters) or more to global sea level.

That may have happened 130,000 years ago, the last time seas rose higher than today. The sheer magnitude of the rise, 15 to 20 feet (five to six meters), points to a contribution from Antarctica as well as Greenland. Then, as now, Antarctica was too cold to melt from above. The attack must have come from warmer oceans that undermined floating ice, triggering a partial collapse of the ice sheet. The stage is set for it to happen again, says Robert Thomas, a glacier expert who works with NASA.

The collapse he envisions would begin at Pine Island, which ends in a floating ice shelf nearly 40 miles (60 kilometers) long. Flying over it in a Chilean Navy plane, Thomas and his colleagues found that the shelf is thinning by tens of feet a year. That explains Pine Island's speedup, says Thomas: The thinning weakens the shelf's grip on the land to either side, releasing the brakes on the glacier. More disturbing to Thomas is the "ice plain" just inland of the floating ice shelf—15 miles (24 kilometers) of dead-flat ice, resting lightly on deep bedrock. The ice plain is also thinning, and Thomas thinks that sometime in the next decade, it will be thin enough to float free.

Once that happens and the ocean intrudes, a chain reaction of collapse could follow. "The bed is very deep and flat for the next 150 miles (240 kilometers) inland, so an enormous fjord would be created in the ice," Thomas says. "That would put the nail in the coffin—it would go on accelerating, retreating, and drain a lot of that part of West Antarctica."

Thomas won't say how fast this gloomy scenario might unfold, and some other glaciologists dismiss it. But the prospect of a sneak attack from warming oceans is worrisome enough that scientists are planning major studies for the International Polar Year, a coordinated polar research effort over the next two years. Robert Bindschadler, a NASA glaciologist, wants to drill through the Pine Island ice shelf—1,800 feet (550 meters) of floating ice—and lower instruments to see whether the ocean really is eroding the underside, and a British group may probe below the shelf with a robotic submarine.

Asked which of the world's great ice sheets worries him more, Greenland or Antarctica, Bindschadler just smiles and says, "Yes." In the thin air of the Andes, doubts evaporate. Here the fate of the ice is as distinct as the jagged gray peaks around the Tuni reservoir, a major water source for Bolivia's capital, La Paz, and its burgeoning slum, El Alto.

Edson Ramírez, a Bolivian glacier researcher, is on his way to check gauges along the mountain streams that fill the reservoir. He stops his truck and unfurls aerial photos of the same peaks, made in 1983. Back then, they were bearded with glaciers. Today the glaciers are shriveled, pocked—or simply gone. A point-by-point comparison shows that half of them have vanished in 20 years, and the total ice area has shrunk by 30 percent.

“In 1995, when we predicted the disappearance of the glaciers, very few people believed us,” Ramírez says. “We were accused of being alarmist. But now it has come to pass.” Global warming apparently struck these glaciers a roundabout blow. Every month for the past 15 years Ramírez and other scientists led by Bernard Francou, a French glaciologist, have climbed glaciers around La Paz to measure the ice and collect weather data. They saw little direct effect from the slight warming of the atmosphere in recent years. What devastated the glaciers was a relentless series of El Niños—episodes of warming in the waters of the equatorial Pacific.

El Niños, which are striking more often as the climate warms, throw global weather out of kilter, starving the tropical Andes of snow. Normally the highest part of a tropical glacier gains thickness from snowfall during the wet season, making up for melting below. But in a snowless year, glaciers gain little ice.

Meanwhile, melting accelerates—because of yet another feedback. Snow normally acts as a protective sunblock for mountain glaciers. On one of Francou’s study glaciers, a two-mile-long (three kilometers) cascade of ice called Zongo, the effect is easy to see. Zongo’s upper slopes glitter with old snow, a legacy of the wet season six months ago. Reflecting the sun’s light and heat, the snow keeps the ice underneath from melting. But the glacier’s lower reaches are bare ice, a dull, dusty gray that absorbs solar heat like a dark T-shirt. By late morning, rivulets of melt are trickling down the ice.

An El Niño—three hit Bolivia in the 1990s—leaves most of the glacier snowless, gray, and vulnerable. Each time, the sun erodes many feet of ice, and the losses are never fully replaced. Since 1991 Zongo’s surface has dropped 20 feet (six meters), and the glacier’s snout has retreated 650 feet (200 meters) upslope, leaving a lake of silty meltwater. Zongo is a relatively healthy glacier—massive and high, topping out above 19,000 feet (5,800 meters). Chacaltaya and the shrinking glaciers around the Tuni reservoir are smaller, lower, and more fragile. No bigger than city parks, and by far the most common kind of glacier in the Andes, they are bound for extinction in the years to come.

The loss of a ski area is sadly symbolic. But the loss of the glaciers could spell real trouble for cities like La Paz, at the receiving end of the canals and power lines that lead out of the mountains. Mountain glaciers play a vital role as water banks, storing it as ice during wet seasons and doling it out in dry months as melt. Ramírez has found that, year-round, glacier runoff supplies about a third of the water in Tuni; in the dry season the figure rises to 60 percent. In Peru, a major hydroelectric plant and a rich agricultural valley depend on the Santa River, where 40 percent of dry-season flow is glacial meltwater. The Ganges, the lifeline for northern India, is by some estimates 70 percent glacial in the summer—runoff from Himalayan ice fields.

The bounty continues for now; in some places, it has even increased, as the glaciers melt faster than ever. But cities and farms downstream will soon feel the pinch. Edson Ramírez expects La Paz and El Alto to face water shortages before the end of the decade, as demand grows and the glacial supply starts to dwindle.

“If you dry up the mountains, what happens to the cities below?” asks Walter Vergara, a Latin America climate-change expert at the World Bank. In the developing world, the question is often asked in anger. “Climate change wasn’t caused by the poor countries like Bolivia,” says Oscar Paz Rada of the Bolivian Ministry of Planning and Development, “and there is a debt owed them by the developed countries.” New dams and bigger reservoirs could keep water flowing through the dry season; wind or solar power could supplement fitful hydroelectric generators.

These measures won’t be cheap, and some, like dams in the earthquake-prone Andes, carry risks of their own. “But time won’t wait,” says Paz. “People need us to take action.” Bernard Francou likes to show a whimsical photo of himself pedaling an ice-cream cart. It is his next career, he jokes, after the ice is gone. Francou is prone to dark humor. From many people whose lives are bound up with ice—scientists, mountaineers, ordinary people who live near the glaciers—you hear a note of mourning.

Glacier National Park in Montana is a fitting emblem for the great change sweeping the world’s cold places. Dan Fagre has studied the glaciers in the park for 15 years. A scientist for the U.S. Geological Survey, he has the numbers at his fingertips: 27 glaciers left in the park out of 150 a century ago, 90 percent of the ice volume gone. He gives the remainder another 25 years. “It will be the first time in at least 7,000 years that this landscape has not had glaciers.”

As a scientist, he is fascinated to watch a planet being transformed. As a human being, he feels the loss of a beloved landscape. “When I go to some of the glaciers I know well, I come over the ridge, and I don’t even have to pull out maps or photos,” he says. “I can just look and go, Oh my gosh, that whole area’s gone.” Another icy landmark, seemingly as permanent as the mountains themselves, has vanished in the heat.