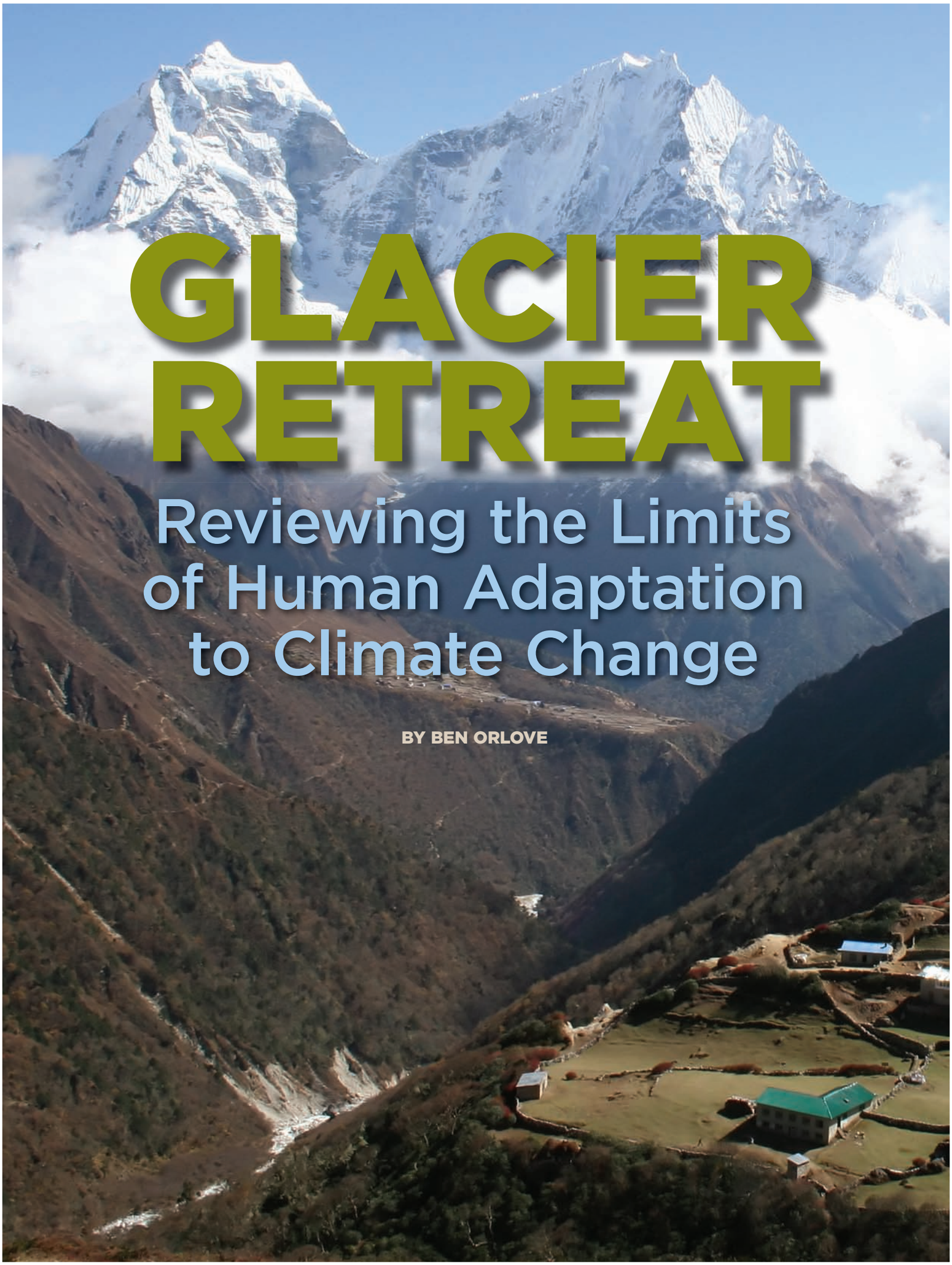

GLACIER RETREAT

Reviewing the Limits of Human Adaptation to Climate Change

BY BEN ORLOVE

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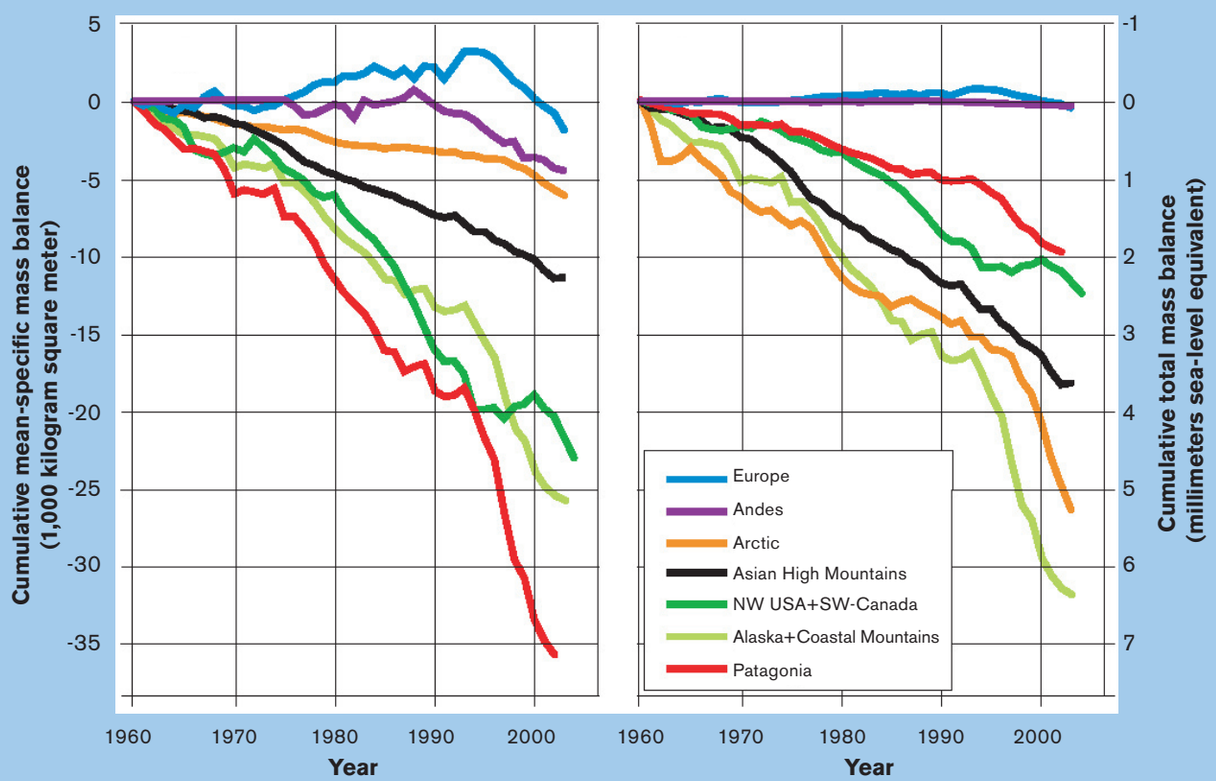
The world's mountains bear many glaciers, somewhere between 150,000 and 200,000 by current estimates.[1] Nearly all are shrinking.[2] As temperatures increase, the massive banks of ice on mountain summits melt much faster than they did in the past. The fresh snows that fall each year cannot make up for this loss, and the glaciers retreat upslope and grow smaller. A recent review of glaciers around the world shows that the average loss of length is about 10 meters (m) per year, and this pace is accelerating in many regions (see Figure 1 below).[3]

Unlike many other consequences of climate change, glacier retreat is highly visible and widely recognized by people around the world. Glacier retreat first became the subject of major headlines and television news stories in 1991, when hikers high up in the Austrian Alps discovered the body of a man half-buried in ice.[4] Though some people thought he was a mountain climber who had died recently, he proved to come from a much more remote time, the Bronze Age, and had lain covered by ice for thousands of years. In other cases, glacier retreat has received media attention because of the fame of the mountains themselves. The rapid loss of glaciers on Mount Kilimanjaro was widely reported[5] because the mountain is a well-known tourist attraction and the setting of Hemingway's famous story, "The Snows of Kilimanjaro." Similarly, Glacier National Park in Montana became the subject of news stories when some of the glaciers for which it was named shrank so much that they were no longer visible from major roads or accessible by short hikes.[6] As the historian Mark Carey has noted, many people speak of glaciers as if they were an endangered species that deserves protection against extinction.[7]

As a result, mountain glaciers powerfully demonstrate how climate change has already altered the world. Numerous surveys show that people believe the most serious impacts will take place far in the future and affect people in remote settings, such as the Arctic, or low-lying atolls in the Pacific Ocean.[8] However, glaciers have been retreating for decades,

Figure 1. Glacier Trends



NOTE: The graph on the left shows the loss of glacier ice per unit area in several regions. The graph on the right shows each region's contribution to sea-level rise. Since 2000, glaciers have been shrinking in all regions, and the pace is accelerating.

SOURCE: P. Lemke et al., "Observations: Changes in Snow, Ice and Frozen Ground," in *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (Cambridge, UK, and New York, NY: Cambridge University Press), 3,598.

in many settings: developed as well as developing nations in North and South America, Europe, and Asia. Even Africa has peaks with shrinking glaciers, both Mount Kilimanjaro in Tanzania and several peaks in the Rwenzoris in Uganda. Indeed, it could be said that glaciers are shrinking on every continent, if one counts New Zealand, with its Southern Alps, as part of greater Australia.

More than many other consequences of climate change, glacier retreat also is easily understood: temperatures warm, and ice melts. The negative consequences of glacier retreat for important issues—water resources, natural hazards, and landscapes—are also straightforward and clear, and significant agreement between expert and lay opinion on its existence, nature, and impacts makes glacier retreat an area of overlap between the views of the scientific community and the general public. Moreover, in recent years, public institutions have formed to address climate change, including the United Nations Framework Convention on Climate Change (UNFCCC), many national and regional bodies, and nongovernmental organizations (NGOs) concerned with sustainable development. Glacier retreat falls clearly within their stated missions. If society cannot address glacier retreat, it is very likely that other aspects of climate change will prove even more intractable. Yet the record on mitigating and adapting to glacier retreat is mixed at best.

Consequences of Glacier Retreat

The long history of glacier research allows scientists to describe glacier dynamics with great confidence.[9] Systematic monitoring, which began in late nineteenth-century Switzerland, has expanded to many other countries, and grew with the use of aerial photography, especially after World War II. Since the mid-1990s, capture and analysis of satellite data have permitted global study of glacier processes. As a result, there is strong support for the statement that glaciers have been retreating in nearly all areas since at least 1980.

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Melting glaciers substantially contribute to sea-level rise, which causes more frequent flooding in low-lying areas like the Piazza San Marco in Venice.

Not only a physical process, glacier retreat also has direct impacts on human well-being. At a global scale, it contributes to sea-level rise, a change with significant consequences in coastal areas around the globe. The reports of the Intergovernmental Panel on Climate Change indicate that sea level rose about 15 centimeters (cm) in the twentieth century. They calculate that mountain glaciers contributed about 27 percent of this amount.[10] (Other portions come from the slight expansion of seawater as it warms and from melting in Greenland.) Though Antarctica and Greenland, which also have been warming, contain much more ice than mountain glaciers, they still remain cold enough that rates of melting are slower. Sea levels are likely to rise more in the current century, perhaps as much as 80 cm–1 m. Glacier meltwater will contribute about 30 percent of this total. The view beyond 2100 is far from clear, though it is quite possible that the remaining mountain glaciers at that time will be too small to add significantly to sea-level rise and that meltwater from Greenland and Antarctica will form a larger part of that process. Even with the present rise, many coastal areas experience increased flooding. For example, the Piazza San Marco, the main square of Venice, is awash with water more often than in the past, requiring construction of wooden walkways for residents and tourists. Though the ground on which the city is built has subsided and the lagoon in which the city is located has also changed, sea-level rise is the largest single factor causing the increased flooding.[11]

Another major set of impacts is associated with water resources. Though glacier retreat can lead to an increase in meltwater that flows through rivers, this phase is often short, lasting only a few years or decades. In most regions of the world, glaciers are now providing less water than before to the rivers immediately below them, reducing the availability of an economically important resource. Moreover, glacier meltwater often comes in relatively dry months, evening out annual fluctuations in river levels and providing water when it is scarcest and most valuable. In the higher portions of the watersheds, people use glacier meltwater to irrigate small-scale mountain agriculture and generate hydropower. In the middle and lower portions of the watersheds, meltwater contributes to urban water supply and helps irrigate commercial agriculture. Growing scarcity can lead to competition and conflict between different uses and between groups in different portions of a watershed (see the box on page 26).

Glacier retreat also leads to a series of natural hazards. Lakes often form at the lower end of melting glaciers. These lakes can be very unstable, and a simple shock—a season of heavy melt, an earthquake, or a large piece of ice breaking off the glacier front—can send an enormous flood rushing downvalley. In other cases, the instability occurs in the exposed slopes of valleys once filled with glaciers; these surfaces are often steep and can collapse in vast rockslides. In one incident in Peru in 1970, more than 20,000 people were killed in a single debris flow that started when a chunk broke off the face of a large glacier, triggered by an earthquake.[12]

In addition to the impacts on water resources and the hazards, glacier retreat can lead to changes in culturally significant landscapes. People often form deep attachments to the beautiful white peaks they see, and they experience a sense of loss when these change. A portion of this loss can be assessed economically, since tourism and recreational visits decline. Much of this loss, though, is more personal and subjective in nature. The indigenous Quechua-speaking villagers in southern Peru who live in the ranges near the Quelccaya ice cap report their distress that the white summits of the nearby peaks, which they understand to be the homes of powerful spirits, are becoming dark.[13] In other parts of the world, the sense of identification with glacier-covered peaks, though not phrased in terms of spirits, is also very strong (see the box on page 27 for an example).

Our Responses to Glacier Retreat

What has been the nature of human response to glacier retreat? It might seem that it is a relatively easy consequence of climate change for society to address, given that both the public and the scientific community recognize the problem and understand its causes and effects. Yet while glacier retreat has promoted public understanding of the consequences of greenhouse gas emissions, nations, NGOs, communities, and other organizations have done relatively little to alleviate the impacts that have taken place and prepare for the ones that will come.

Mitigation

The visibility of glacier retreat and its impacts on culturally valued landscapes have helped contribute to global awareness of climate change and support for mitigation policies. Before-and-after pictures, which Al Gore used effectively in *An Inconvenient Truth,* resonate with viewers around the world (see Figure 2 on page 28). For many people, these images have become part of the everyday understanding of the Earth. They convey the fragility of our world and the relentless pace of climate change, and they reinforce media stories that report quantitative information, often in the form of percentages of loss, about glaciers in different regions.

However, the other impacts of glacier retreat are less well known and have had less influence on public opinion and mitigation policy. For instance, though mountain glaciers have contributed more to sea-level rise than the ice sheets in Antarctica and Greenland, they are less associated with this problem in the public imagination because of the broad awareness of the vast extent of the ice sheets and the risks that their melting can create in the future. In addition, mountains are far from

WATER IN CENTRAL ASIA

The two large rivers that drain west from the glacier-covered ranges of central Asia offer an illustrative case of the limits of adapting to glacier retreat. The Syr Darya originates in the peaks of the Tien Shan and Pamir in Kyrgyzstan, at elevations above 7,000 meters, and flows through Kyrgyzstan, Tajikistan, and Uzbekistan into Kazakhstan, where it empties into the Aral Sea. The Amu Darya flows from glaciers of the Pamirs of Tajikistan. It forms first the border between Tajikistan and Afghanistan and then the border between Turkmenistan and Uzbekistan before flowing into the Aral Sea. In recent decades, Kyrgyzstan and Tajikistan, located at higher elevations in more mountainous terrain, bartered hydropower-generated electricity to Uzbekistan and Kazakhstan for coal and gas, but they have found that these deliveries have been unreliable, especially since the decline of the Soviet Union.

Uzbekistan and Tajikistan, which lie at lower elevations in flatter terrain, use water to irrigate cotton and other crops. The extensive withdrawals from the rivers have contributed to the decline of wetlands in the river's lower course and to the shrinkage of the Aral Sea, once one of the world's largest lakes. The once-extensive fisheries in the lake have entirely collapsed. In recent years, Kyrgyzstan has released a good deal of water in the winter to generate energy at the time of peak demand; as a result, less water is available in the reservoirs to release for summer irrigation downstream.

These nations in the Aral Sea basin all seek to maximize their own use of water, particularly for irrigation and, in the cases of Kyrgyzstan and Tajikistan, for hydropower. The downstream nations complain that the upstream nations fail to deliver water of sufficient quantity and quality, while the upstream nations charge that the downstream nations do not honor agreements to provide energy and monetary payments. The ethnic and linguistic differences in the basin compound these tensions.

Seeking to promote sustainable development and efficient use of resources, the World Bank and the United Nations Development Programme sponsored international agreements between the countries and some of their neighbors in 1992–1995 and 2002. However, water-related tensions remain high. These conflicts are exacerbated by glacier retreat, since the river now carries less water, and the crucial summer flow has been particularly reduced.

Sources: E. Weinthal, "Water Conflict and Cooperation in Central Asia," Human Development Report Office Occasional Paper 32 (New York: United Nations Development Programme, 2006); and U. Luterbacher, V. Kuzmichenok, G. Shalpykova, and E. Wiegandt, "Glaciers and Efficient Water Use in Central Asia," in B. Orlove, E. Wiegandt, and B. H. Luckman, eds., *Darkening Peaks: Glacier Retreat, Science, and Society* (Berkeley, CA: University of California Press, 2008), 249–57.

oceans, and the link between mountain glaciers and sea level is less immediate than in high-latitude areas, where images of collapsing ice shelves and shrinking sea ice are widespread.

In Western Europe, where images of the Alps are widely distributed, the public better recognizes impacts of glacier retreat on mountain populations than in the United States. When Americans think of the people who have already been impacted by climate change, their minds tend to turn to the Inuit and the inhabitants of low-lying atolls.[14] Several factors might account for this. The mountain glaciers are widely dispersed, fragmenting public attention, whereas the Inuit are all located in the Arctic, and the threatened islands are concentrated in the Western Pacific and Indian Oceans. Moreover, the before-and-after images, strong as they are, do not have the emotional power of the images of a polar bear on a tiny ice floe or of waves moving beyond the top of a beach to strike palm trees and houses. The Arctic and the atolls are represented by effective organizations: the Inuit Circumpolar Council, which contributed actively to the highly visible Arctic Climate Impact Assessment, and the Association of Small Island States, which has an active presence at UNFCCC meetings. Organizations that represent mountain regions, such as the International Centre for Integrated Mountain Development, tend to address a variety of development and environmental issues and, as a result, do not provide strong reinforcement to glacier retreat as a distinct issue.

ARMENIAN COATS OF ARMS

The history of the coats of arms of Armenia suggests the symbolic importance that glaciers may hold. The coat of arms of the Armenian Soviet Socialist Republic contains at its center Mount Ararat, which is located within Turkey but was within the territory of medieval Armenian kingdoms. The mountain is surrounded by wheat and grapes, indicating the agricultural nature of Armenia and perhaps hinting at its Christian identity as well, since wine plays an important role in Christian rituals and is forbidden to Muslims. The hammer and sickle and the red star, important Soviet symbols, are prominently featured.

The coat of arms of the Democratic Republic of Armenia also contains Mount Ararat at its center, now featuring a small boat on its summit, Noah's Ark, believed to have settled there after the Biblical Flood. This image may also hint at the Christian identity of Armenia, since the Quran, which also describes a flood, states that the resting place of the ark is Mount Judi, further to the south in Turkey near borders with Iraq and Syria. In this second coat of arms, the mountain is surrounded by four smaller symbols, an eagle, and a lion, all representing earlier dynasties that had ruled an independent Armenia at different times since the first century B.C.

As these two coats of arms indicate, the high white peak of Mount Ararat is of great importance to Armenians. Visible from the capital of Yerevan and much of Armenia, the mountain serves as a symbol of the Armenian people and nation, of their great history, and of their will to survive under foreign domination.

The seal of the Armenian Soviet Social Republic, in official use 1936–1991.

The seal of the Republic of Armenia, adopted in 1992.

Adaptation

Unfortunately, a review of the literature reveals only a few cases of effective adaptation to glacier retreat. For example, though Norway has abundant natural gas resources, it is committed to sustainable energy practices, and nearly all the electricity it produces—both for domestic use and export—comes from hydropower.[15] Faced with reduction in water supplies in its glacier-covered watersheds, the Norwegian Water Resources and Energy Directorate, the agency responsible for the administration of the country's water and energy resources, weighs the siting of future plants carefully. It considers the past, present, and future hydrology of different basins, the current and projected structure of the Scandinavian electric grid, and trends in energy demand. The agency plans to phase in other sources of sustainable energy, particularly wind, a resource Norway also has in abundance, despite the high initial costs of developing it.[16]

Switzerland has a long history of avalanches, landslides, and severe flooding. In recent decades, the risk of landslides and lake outburst floods associated with glacier retreat has increased along with other climate change impacts, such as permafrost loss. A series of severe floods in several glaciated cantons—the semi-autonomous states that make up Switzerland—led the Swiss Federal Office for the Environment to expand its program of hazard mapping.[17] This agency produces maps with four different zones, providing information to residents in the second, low-risk zone; restricting construction in the third, medium-risk zone; and prohibiting it entirely in the fourth, highest-risk zone. These maps serve as a basis for cantonal and communal planning. This effort has required considerable negotiation with the cantonal authorities,

Figure 2. Shepard Glacier, Glacier National Park, MT, 1913 and 2005

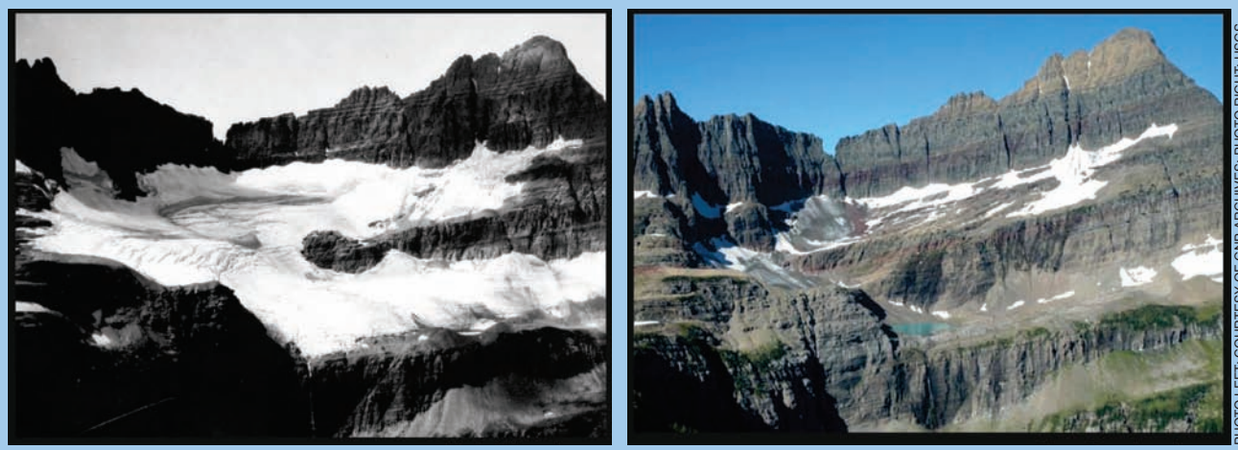

PHOTO LEFT: COURTESY OF GNP ARCHIVES; PHOTO RIGHT: USGS

1913 2005

SOURCE: U.S. Geological Survey Repeat Photography Project, http://nrmsc.usgs.gov/repeatphoto.

which historically have had great flexibility in setting policy within Switzerland's decentralized system. Local landowners and communal authorities also have experienced tense negotiations with the experts who produce the map, since a classification into the higher zones can reduce the value of property.

On a much smaller scale, some of the mountain resorts that derive income from tourists who seek glacier-related recreation have sought adaptation measures. Some, such as the Kaprun ski resort on the Kitzsteinhorn glacier in Austria, add runs at higher elevations, moving upslope with the ice and snow.[18] Others, recognizing that the glaciers will continue to shrink, develop other forms of recreation that do not require the presence of snow, such as mountain biking.

Other resorts seek to maintain the glacier. These responses are less clearly adaptive since they entail significant costs that reduce the potential benefits of adaptation. Some Swiss and Austrian resorts spread foam or cloth coverings on the glaciers to protect them during the summer so that they will be available for skiing in late autumn and early spring. The Whistler-Blackcomb ski resort in British Columbia uses snowmaking machines to spray artificial snow onto the surface of its glaciers; it produced 500,000 cubic meters of snow in 2006.[19] A recent survey found such snowmaking operations at ski resorts in the Alps were effective only in terms of direct financial costs to the ski operations; the snowmaking becomes unprofitable if one takes into account all the costs, such as potential unintended consequences on water consumption, energy demand, and environmental quality.[20] Moreover, warmer temperatures in later decades in this century will make these efforts entirely unviable.

Yet other resorts move existing snow. The managers of the Italian ski resort at the Vedretta Piana use snowplows to push snow from the highest portions of the glacier to the ski runs. This practice makes the resort more attractive to skiers in late summer but hastens the demise of the glacier by bringing the snow that could replenish it to lower elevations, where it melts more quickly.[21]

The Sustainable Slopes program of the U.S. National Ski Area Association, established in 2000, promotes the mitigation of greenhouse gases by offering discounts to visitors who carpool or purchase carbon offsets. Several member resorts have runs on glaciers. This and other similar "ski green" initiatives will contribute very little directly to reducing glacier retreat, since car trips to ski resorts account for a minute fraction of global greenhouse gas emissions, though they do serve to build awareness of the issue—and to promote the resorts to environmentally conscious individuals.[22]

Limits to Adaptation

Some additional cases could be mentioned, but many more examples illustrate the lack of adaptation. For instance, Nepal, like Norway, generates significant hydropower from glacier-fed rivers, but it faces far greater obstacles in adapting its energy sector to glacier retreat. The rugged topography of the Himalayas, the great poverty of the country, and the relatively weak state create what environmental economist Neil Adger and others have called "limits to adaptation."[23]

Nepal relies on hydropower for more than 90 percent of its domestic electricity supply and has the potential to develop hydropower exports.[24] Many of the rivers that provide water for hydropower originate in glacier-covered sections of the Himalayas. As glaciers retreat, water supplies become scarcer, especially in the crucial months before the onset of the summer monsoon. Moreover, glacier retreat increases the risk of glacial lake outburst floods. Some of these are quite severe; during an outburst flood in 1985,

a wall of water and debris more than 10 m high rushed along a distance of more than 90 kilometers, washing away many terraced fields. It destroyed 14 bridges and a nearly completed hydroelectric plant. At least seven other such events, though smaller in scale, have taken place since 1970, and a recent survey identified 20 potential flood sites.[25]

It is difficult to construct solutions to address both the long-term declines of water supply and increased risk of outburst floods, particularly granted Nepal's poverty and endemic political tensions. The country might choose to site future hydroelectric plants in low-risk locations. However, Nepalese authorities have not fully assessed the risks: the low-risk locations might have lower hydropower potential or higher transmission costs, and existing hydropower facilities would remain vulnerable to floods. An alternate strategy would be to shift to microhydropower facilities, drawing on simple technologies to supply rural areas with power. A network of many small sites would be less vulnerable to single flood events than a network with fewer large sites. However, the decrease in water supply might make the small facilities less viable, since they are less able to store water for dry months and years.

Nepal could set up early warning systems, possibly deriving information from satellite monitoring of lakes, though these systems are difficult to install in the steep terrain of Nepal, where communications technologies are often limited. In 1997, Nepalese took on a more direct means of reducing risks by draining a particularly dangerous lake. Sitting at an elevation of about 5,000 m, Lake Tsho Rolpa had grown more than sevenfold in size. A natural moraine dam held a large volume of water; if the dam had breached, an outburst flood would have damaged or destroyed a large hydropower plant under construction. With support from the Netherlands Development Agency, the Nepalese government consulted experts, who recommended digging a channel to lower the lake and constructing a gate that could release water when needed. The project, completed in 2002, reduced the risk of an outburst flood by 20 percent and cost more than US$3 million; further reductions would be much more expensive. It also included an early warning system that involved over a dozen villages downstream. The Lake Tsho Rolpa case shows the long time frame and high expenses needed to reduce risk—serious obstacles for a poor country like Nepal, since funds are also needed to support the development of new hydropower facilities.

A review of adaptation efforts more broadly indicates that when governments pay attention to water resources in glacier-covered watersheds, they typically

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A number of ski resorts around the world feature runs on the surface of glaciers. This resort, Chacaltaya in Bolivia, has been abandoned because of glacier retreat.

concentrate on hydropower, urban water supply, and, to a lesser extent, commercial irrigated agriculture in the lowlands.[26] Often overlooked are the small-scale mountain herders and farmers in many regions of the world—such as the Ecuadorian, Peruvian, and Bolivian Andes; the Himalayas of Nepal and India; and the Karakoram of India and Pakistan—who face reductions in water supplies that make it difficult for them to irrigate their fields and provide pasture for their flocks.[27] Even in the Alps, a fairly prosperous region, many farmers lack the water they need to irrigate their fields, especially in the drier valleys that lie in the rain shadow of high ranges.[28] Worldwide, these mountain populations number in the tens of millions, yet receive relatively little attention. The ad hoc responses of the farmers—digging new irrigation channels, shifting to more drought-tolerant crops and crop varieties, and seeking off-farm income—compensate only partially for the losses that they have faced, and it is probable that migration to other areas, already present for other economic and social reasons, will become more common as glacier retreat further reduces water supplies.[29]

COURTESY OF UNEP/RRC-AP, ICIMOD

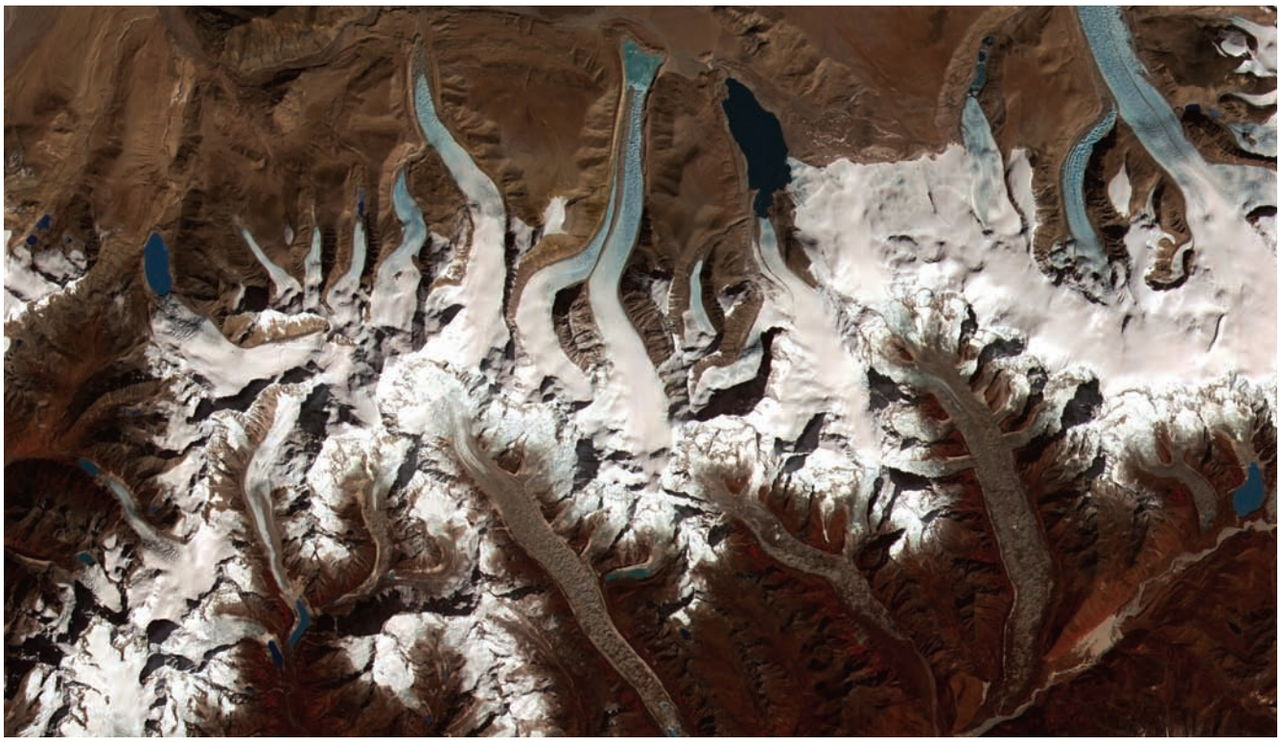
The dangerously large Lake Tsho Rolpa in Nepal was manually lowered in 2002 at the cost of US$3 million, reducing the risk of floods.

Two broad problems have impeded the development of effective adaptation programs to glacier retreat. The first can be called the "multiple impacts problem." As we have seen, glacier retreat affects water resources, natural hazards, and culturally significant landscapes. Multifaceted problems are often more difficult to face than simple ones, as indicated by the choices Nepal faces in balancing hydropower development and hazard management. This problem comprises several connected problems. The "multiple scales problem"[30] stems from the fact that the impacts of glacier retreat occur on different spatial and temporal scales. For example, hazards can be localized, but culturally significant landscapes are appreciated on regional or larger scales, and water resource problems may be felt before sea-level rise. The "valuation problem"[31] involves the comparison of very different entities: the relation between water resources and hazards is not a comparison between apples and oranges but between apples and an orange tree crashing through the roof. As a result of the multiplicity of problems, some groups—often the most vocal or powerful—can articulate their concerns and gain access to adaptation funds. Where only a single impact is dominant, as in the case of Norwegian Water Resources and Energy Directorate or the ski resorts, adaptation may be simpler.

The second overarching difficulty can be called the "responsibility problem."[32] Which organizations or institutions have the legitimate authority and widely recognized obligation to address these impacts through adaptation programs? Corporations, whether public, as the Norwegian hydropower agency, or private, as the ski resorts, can operate effectively within certain areas but do not address many impacts of great concern. Local communities can handle many environmental problems, but trying to address glacier retreat would overwhelm their limited resources. Watershed councils operate around the world on different scales: farmers organize small irrigation districts; common-property managers, landowners, and resource managers coordinate plans for sustainable water use on medium-sized rivers; and nations develop agreements for international river basins. These groups have the advantage of long time horizons, corresponding to the time scale of glacier retreat.

But the watersheds that undergo glacier retreat often include widely disparate users. The notion of stakeholders is closely associated with integrated water resource management and watershed governance, but it is difficult to apply this term—with its associations of equality and participation—to groups as diverse as small-scale mountain farmers, hydropower managers, and urban hazard specialists. Because of the weaknesses of other organizations, national governments might seem best suited to take responsibility for glacier retreat. The UNFCCC emphasizes this scale since its members are nations. While we have seen some positive cases of adaptation at the national level, these are principally found in rich countries such as Norway and Switzerland. In addition, the multiple-impacts problem often leads nations to address only some effects, often those articulated by more powerful interests, and the long time horizon of glacier retreat may not match well with the shorter time scales of elected officials and even of agency administrators.

These problems are illustrated by a case from highland Peru. A recent study[33] traces the organizations in Peru charged with climate issues, including CONAM, the Peruvian National Council for the Environment, and PROCLIM, the Program for Strengthening National Capacities to Manage the Impacts of Climate Change and Air Pollution. In 2008, these agencies received funding for the Adaptation to the Impact of Rapid Glacier Retreat in the Tropical Andes Project. This project, sponsored by the Special Climate Change



COURTESY OF JEFFREY KARGEL, USGS/NASA JPL/AGU

As glaciers retreat in the Bhutan Himalayas, several have new unstable lakes at their bases.

© BRUCE YEUNG/SHUTTERSTOCK

Small-scale farmers in the Himalayas and elsewhere have faced dwindling water supplies to irrigate their fields in recent decades because of glacier retreat.

MISMATCHED CONCERNS

A recent study of a small sample of indigenous herders in the department of Cusco in highland Peru and the intermediate organizations operating there shows a striking divergence in the concerns of the two groups. Researchers conducted interviews with 10 herders and assembled descriptions of the 10 most recent projects of the organizations—two large Peruvian nongovernmental organizations (NGOs), one international NGO, and one European overseas development program. They looked to see whether the area and time frame of the projects matched the concerns of the local residents. For example, a herder might speak of a set of nearby villages with a time horizon of generations, while a project might be part of a program that covers all of highland Peru, with activities and benefits that extend for several years (See Table 1 below). Both dimensions were coded on a five-point ordinal scale, with 1 being the smallest measure and 5 the largest. Given the very small size of the samples, the results can only be taken as suggestive. Nonetheless, they do point toward a difference between the two groups. As members of long-established communities, the herders include the distant future among the periods that they consider; by contrast, the staff of organizations that promote adaptation think on a shorter timescale, typically the multiyear cycle of projects. The herders also prioritize local issues over regional and national ones, while the organizations focus on larger areas.

Source: B. Orlove, "The Past, the Present, and Some Possible Futures of Adaptation," in W. N. Adger, I. Lorenzoni, and K. O'Brien, eds., *Adapting to Climate Change: Thresholds, Values, Governance* (Cambridge, UK: Cambridge University Press, 2009), 131–63.

Table 1. Mismatched scales of concern between herders and development projects in Peru

Temporal scale of concern	Spatial scale of concern: Local community	Nearby communities	Nearby provinces	Highland Peru	All Peru
A few years		3		1	3
A decade	1		1	4	3
Several decades		1			
A century					
Remote future	1	1	1		

NOTE: Blue numbers indicate the number of herders in each cell. Orange numbers indicate the number of projects.

Fund of Global Environmental Facility, has a budget of US$33 million that supports more than four years of activities, a very large sum by the standards of adaptation projects worldwide. The World Bank, the largest single international donor, contributed US$7.5 million. The stated goal of the project—"to contribute to strengthening the resilience of local ecosystems and economies to the impacts of glacier retreat in the Tropical Andes, through the implementation of specific pilot adaptation activities that illustrate the costs and benefits of adaptation,"[34]—complements its justification, which emphasizes the poverty of the highland regions.

Glacier retreat will have many consequences for Peru's glacier-covered watersheds. These include the growing scarcity of water for agriculture, hydropower, and urban supplies; increased risks of landslides and outburst floods; and changes in culturally significant landscapes since the white peaks of the Andes are deeply cherished by indigenous and *mestizo* Peruvians alike.[35] Yet government agencies focus their efforts on hydropower.

This fact also illustrates the responsibility problem because hydropower is especially crucial to Peru's cities and mining enterprises, both of which carry significant political weight. The project will support glacial monitoring and reforestation in the Shullcas and Santa Teresa basins, two small landslide-prone, glacier-covered watersheds—with relatively small populations and irrigated areas—that contain hydroelectric plants scheduled for expansion. Though later phases of the project may address the local rural populations most acutely affected by glacier retreat, these two activities suggest that the project's priorities lie elsewhere, even though the extreme poverty in rural areas serve to justify the project.

The responsibility problem is present for other actors in this setting as well. The NGOs that receive funding to support the indigenous livestock herders in the high mountain regions have not yet identified effective ways to respond to the challenges of glacier retreat, especially the declining availability of water for livestock and pasture; they promote activities such as the introduction of new varieties of pasture and new livestock breeds, which require more water and hence are ineffective in the context of decreasing water availability. The box above illustrates the divergent perspectives of the herders and NGOs who might be involved in jointly designing adaptation to glacier retreat in this region.

Possible Routes toward Adaptation

These two problems may have a common solution: groups of organizations could address the multiple impacts and scales by sharing responsibility for adapting to glacier retreat in a framework that some have termed "network governance."[36] International organizations, national governments, NGOs, and local communities could work together, drawing on their complementary strengths. In particular, local communities often possess detailed knowledge of their environments and can also mobilize their members to work in a variety of activities. National governments and international organizations have access to financial resources and can draw on information about new technologies. The case of hazard mapping in Switzerland is a successful example of such joint efforts between national, regional, and local governments. But even in this instance, located in a stable, prosperous democracy, issues of trust were significant; local officials faced conflicting pressures from their constituents and national agencies. The difficulties are even greater in the Peruvian example, discussed above, in which some groups have far better access to enter governance networks than others, and in the case of water resources in Central Asia (see the box on page 26), which shows the resistance of some parties to the efforts of international bodies to promote the establishment of linkages between different actors.

Although the examples from Peru and Nepal illustrate the obstacles such networks face, the collective will to address these problems may expand. The growing global attention to climate change and the expanding body of work on adaptation in other sectors could support such integrated efforts. Without them, though, adaptation to glacier retreat will advance slowly, while the consequences continue to worsen.

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