GOING, GOING, GONE!

Climate Change & Global Glacier Decline

Dramatic changes can be seen over a 23 year period at the Aletsch Glacier in Valais, Switzerland. Back in 1979, the end of the glacier reached far down the mountain slopes. By 2002, considerable glacier retreat is visible. The glacier's end is nearly out of sight and new vegetation is covering the slopes.
© Pro Natura Zentrum Aletsch Laudo ALBRECHT

Global Warming is melting glaciers in every region of the world, putting millions of people at risk from floods, droughts and lack of drinking water.

Glaciers are ancient rivers of compressed snow that creep through the landscape, shaping the planet's surface. They are the Earth's largest freshwater reservoir, collectively covering an area the size of South America. Glaciers have been retreating worldwide since the end of the Little Ice Age (around 1850), but **in recent decades glaciers have begun melting at rates that cannot be explained by historical trends[1].**

Projected climate change over the next century will further affect the rate at which glaciers melt. Average global temperatures are expected to rise 1.4-5.8ºC by the end of the 21st century[2]. Simulations project that **a 4ºC rise in temperature would eliminate nearly all of the world's glaciers** (the melt-down of the Greenland ice sheets could be triggered at a temperature increase of 2 to 3ºC). Even in the least damaging scenario – a 1ºC rise along with an increase in rain and snow – glaciers will continue to lose volume over the coming century[3].

Although only a small fraction of the planet's permanent ice is stored outside of Greenland and Antarctica, these glaciers are extremely important because they respond rapidly to climate change and their loss directly affects human populations and ecosystems. **Continued, widespread melting of glaciers during the coming century will lead to floods, water shortages for millions of people, and sea level rise threatening and destroying coastal communities and habitats.**

Regions At Risk

- **Ecuador, Peru and Bolivia** – where shrinking glaciers supply water year-round, and are often the sole source of water for major cities during dry seasons.
- **The Himalayas** – where the danger of catastrophic flooding is severe, and glacier-fed rivers supply water to one third of the world's population.
- **Small island nations** such as Tuvalu and some of the Solomon Islands – where sea level rise is submerging low-lying land and saltwater is inundating vital groundwater reserves.

Nature At Risk

- **Royal Bengal tiger** – endangered tigers that will lose a large portion of their worldwide habitat as the Sundarbans succumb to sea level rise.
- **Kittlitz's murrelet** – rare birds specialized to hunt in cloudy glacier water and nest on top of ice.
- **Coral reefs** – unique organisms that can be starved of energy from the sun when sea levels rise.

Rising sea level will submerge small island nations. Salty sea water will also make their groundwater undrinkable.
© WWF-Canon / Soh Koon CHNG

Since the early 1960s, mountain glaciers worldwide have experienced an estimated net loss of over 4000 cubic kilometers of water – more than the annual discharge of the Orinoco, Congo, Yangtze and Mississippi Rivers combined; this loss was more than twice as fast in the 1990s than during previous decades.

Measuring Glacier Loss

The most accurate measure of glacier change is mass balance, the difference between accumulation (mass added as snow) and ablation (mass lost due to melting or calving off of chunks). Even if precipitation increases, mass balance may decline if warmer temperatures cause precipitation to fall as rain rather than snow. Mass change is reported in cubic meters of water lost, or as thickness averaged over the entire area of the glacier. Because mass changes are difficult to measure, glacier shrinkage is more often described as a loss of glacier area, or as the distance the front (terminus) of the glacier has retreated.

Habitat Loss

While many species are likely to be affected by changes in stream flow and sea level associated with glacier melting, animals that dwell on or near glaciers may be pushed towards extinction by the disappearance of their icy habitats. Far from being barren expanses of ice, glaciers are home to some of the most unique organisms and ecosystems on Earth. For example, the tiny ice worm spends its entire life on ice, roaming over glaciers at night, feeding on glacial algae, and occasionally being snatched up by a hungry snow bunting[46]. The physiological adaptation that allows these worms to survive at 0ºC remains unknown, and because these worms disintegrate at temperatures over 5ºC, their secret may be lost as temperatures rise and their glacial habitat melts away.

The Kittlitz's murrelet is found only in Alaska and portions of the Russian Far East. Because of their affinity to glaciers, their survival is threatened.
© Bob DAY

Corals need light in order to survive, but as sea level rises the deeper water can block the sun's nourishing rays.
© WWF-Canon / Jürgen FREUND

Pesticides used in temperate and tropical areas are transported to the Arctic and deposited in glacial ice.
© WWF-Canon / Mauri RAUTKARI

Climate change has already led to the loss of an entire ecosystem on the crumbling ice shelves of the Arctic. Between 2000 and 2002, Ward Hunt Ice Shelf off of Ellesmere Island in Canada broke in two, draining much of the water from overlying Disraeli Fjord, the largest remaining epishelf (ice shelf-bounded) lake in the Northern Hemisphere. This 3000-year old lake supported a rare ecosystem where microscopic marine organisms near the bottom of the lake lived in harmony with their freshwater brethren in the brackish surface waters. **By 2002, 96% of this unique low-salinity habitat had been lost**[42].

Even animals that do not live directly on glaciers can be severely affected by their disappearance. Kittlitz's murrelet, for example, is a small, diving seabird that forages for food almost exclusively in areas where glacial meltwater enters the ocean. These birds are already in serious trouble; their global population (located mostly in Alaska) is thought to have plummeted from several hundred thousand in 1972 to less than 20,000 in the early 1990s[41]. Several conservation groups have filed a petition to declare Kittlitz's murrelet an **endangered species**, citing climate change and the loss of critical glacier-associated habitat as one of the primary reasons for the species' decline.

Even farther away from the melting glaciers themselves, coral reefs will be affected by rising sea level. Corals require light for photosynthesis to survive. The depth at which corals can live is limited by how far light can penetrate the water. When light diminishes as sea level rises, corals living at this light limiting depth will be lost[47]. Coral reefs at other depths will also see reduced growth rates as light quality changes from rising sea level. In one simulation, it was shown that coral reefs in the Caribbean are not expected to be able to keep up with sea level rise[48]. This has consequences not only for the corals and marine life, but for the human communities that rely on these reefs for subsistence.

Contaminants

Although persistent organic pollutants (POPs) such as PCBs and DDT are widely banned today, they were used extensively in the middle of the last century. These long-lived pollutants are transported in the air from their source to cooler areas where they condense and are deposited in glacial ice. Until recently, these compounds had remained trapped in the ice, but rapid melting has begun to release them back into the environment. For example, in one Canadian lake, **glacial meltwater is the source of 50-97% of the various POPs entering the lake**[17]**.** At least 10% of this glacial melt is from ice that was deposited between the 1950s and 1970s, as shown by the presence of tritium, a by-product of nuclear bomb tests conducted during this era.

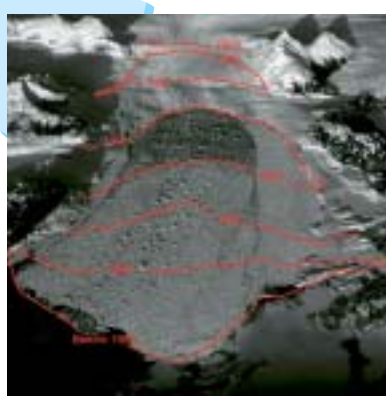
Exit Glacier from camp ground Kenai Fjords National Park Alaska, USA
© WWF-Canon / Anthony B. RATH

The Arctic

Over recent decades, Arctic glaciers have generally been shrinking, with the exception of Scandinavia and Iceland, where increased precipitation has resulted in a positive balance[36]. **Arctic melting appears to have accelerated in the late 1990s; estimates of combined annual melting rose from 100 sq km per year from 1980-89 to 320 sq km in 1997 and 540 sq km in 1998**[37]. Greenland alone contains 12% of the world's ice. While portions of the interior are gaining mass, there has been significant thinning and ice loss around the periphery. This loss is not simply due to melting at the edges; entire portions of the Greenland ice sheet appear to be sliding towards the sea. Because this sliding accelerates when surface melting is most intense, it is believed that surface meltwater may be trickling down to the glacial bed and lubricating ice sheet movement[38]. This recent discovery provides a mechanism for rapid response of ice sheets to climate change, a process that was previously believed to require hundreds or thousands of years.

North America

Glaciers in the Rocky Mountains and Western Coastal Ranges have experienced considerable losses during this century, and melting is accelerating rapidly in southern Alaska. **Since Glacier National Park (Montana, USA) was established in 1910, more than two thirds of its glaciers and about 75% of its glacier area has disappeared[29]; if the present rate of warming continues, there will be no glaciers left in the Park by 2030[30].** In Banff, Jasper, and Yoho National Parks in the Canadian Rockies, glacier cover has decreased by at least 25% during the 20th century[31]. South Cascade Glacier in coastal Washington (USA) lost 19 m of ice thickness between 1976 and 1995, ten times more than during the previous 18 years[32]. Nearly all glaciers surveyed in Alaska are melting, and thinning rates in the last 5-7 years are more than twice those seen in previous decades[13].



Columbia Glacier thinned by 300 m at its oceanfront terminus from the 1950s to 1995, and an astounding 150 meters more in just the 5 years from 1995-2000.
© Mark F. MEIER

According to recent research by NASA, the Patagonia icefields of Chile and Argentina are thinning at an accelerating pace and now account for nearly 10 percent of global sea-level change from mountain glaciers.
© WWF-Canon / Michel GUNTHER

South America

The northern Andes contain the largest concentration of glaciers in the tropics, but these glaciers are receding rapidly and losses have accelerated during the 1990s. In Peru, Yanamarey Glacier lost a quarter of its area during the last fifty years[25], and Uruashraju and Broggi Glaciers lost 40-50% of their length from 1948-1990[26]. In Ecuador, Antizana Glacier shrank 7-8 times faster during the 1990s than in previous decades. Similarly, Glacier Chacaltaya (Bolivia) lost nearly half of its area and two thirds of its volume during the mid-1990s alone, and could disappear by 2010[27]. In the sub-tropical wet Andes, the large ice masses of the North Patagonia Icefield (Chile) and South Patagonia Icefield (Chile and Argentina) had lost only 4-6% of their 1945 area by the mid 1990s[28], but thinning has accelerated recently. Parts of the southern icefield experienced thinning rates from 1995-2000 that were over twice as fast as their average rates during the previous three decades[14].

Antarctica

Antarctica is blanketed by ice sheets that contain about 95% of the planet's freshwater. Cold temperatures prevent significant surface melting, but recent work shows that bottom **melting underneath glaciers at the junction between land and sea is rapid and widespread throughout Antarctica,** possibly due to increased ocean temperatures[39]. Warmer seas have also contributed to the rapid thinning and breakup of many large, floating ice shelves. These shelves may buttress and slow the glaciers flowing into them; although there was no change in glacier velocity after the loss of the Wordie Ice Shelf, several major ice streams that nourished the Larsen A shelf are flowing as much as 2-3 times faster towards the sea since its breakup in 1995[40]. At the same time, the interior has experienced an increase in accumulation because more water is being evaporated from warmer seas and falling as snow[2]. The extent to which these gains compensate for ice loss at the edges is unknown.

Of all the world's glaciers, Antarctic ice will contribute the most significantly to global sea level rise. Its glaciers flow across the continent towards the coast where the ice melts or breaks away to produce icebergs.
© WWF / Fritz PÖLKING

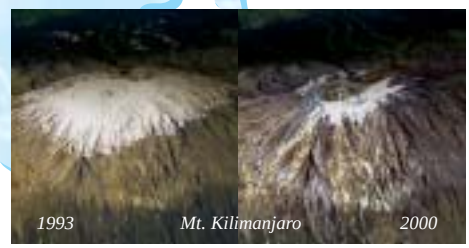
Europe

In the past four decades, the majority of glaciers in the Alps have experienced considerable mass losses; this is illustrated by the Hintereisferner (Austria), Gries (Switzerland), and Sarennes (France), each of which lost the equivalent of 14 m ice thickness since the 1960s. **Glacier melting has accelerated since 1980, and 10-20% of glacier ice in the Alps was lost in less than two decades[18].** The discovery of a 5300-year old ice man in a melting glacier in Italy demonstrates that many glaciers are now smaller than they have been for thousands of years. The World Meteorological Organization reports that summer 2003 temperatures, which triggered floods, land slides, and the rapid formation of glacial lakes, were the hottest ever recorded in northern and central Europe; if current trends continue, the European Alps will lose major parts of their glacier coverage within the next few decades[18].

Glaciers and stream Cogne Valley. Grand Paradiso National Park. Italy.
© WWF-Canon / Michèle DÉPRAZ

Africa

Tropical glaciers in Africa have decreased in area by 60-70% on average since the early 1900s. **The ice fields atop Mt. Kilimanjaro have lost 80% of their area during this century and despite persisting for over 10,000 years, they are likely to disappear by 2020[19].** On Mt. Kenya, 7 of the 18 glaciers present in 1900 had disappeared by 1993[20], and four glaciers (Lewis, Tyndall, Gregory and Cesar) had lost between 60% and 92% of their area. The remaining glaciers in the Ruwenzori Mountains of Uganda and the Democratic Republic of Congo are also melting rapidly, with area losses during the 20th century ranging from 53% (Speke) to 90% (Moore)[21].



Melting snows of Kilimanjaro
The snows of Kilimanjaro formed some 11,000 years ago but some scientists now believe that it will melt away over the next two decades. These satellite images captured dramatic changes between 1993 and 2000.
© NASA and USGS

Himalayan glacier lake. Khumbu valley, Annapurna region, Nepal
© WWF-Canon
NEYRET & BENASTAR

Drinking water is already scarce in parts of Asia where Himalayan glaciers supply freshwater to a third of the world's population. In Bhutan, wooden troughs made from hollowed tree branches carry glacial runoff to communities.
© WWF-Canon / Roel A. BURGLER

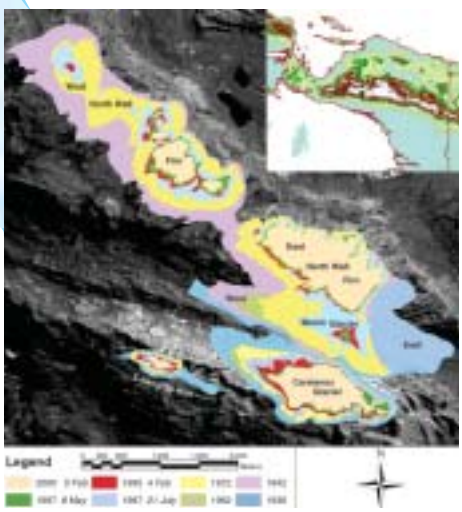
Asia

The vast majority of all Himalayan glaciers have been retreating and thinning over the past 30 years, with accelerated losses in the last decade. For example, glaciers in the Bhutan Himalayas are now retreating at an average rate of 30-40 m per year[22]. In Central Asia, glaciers are wasting at exceptionally high rates. In the northern Tien Shan (Kazakhstan), glaciers have been collectively losing 2 sq km of ice (0.7% of their total mass) per year since 1955, and Tuyuksu glacier has receded nearly a kilometer since 1923[10]. Glaciers in the Ak-shirak Range (Kyrgyzstan) have lost 23% of their area since 1977[23], similar to area losses in the northern Tien Shan (29% from 1955-1990) and the Pamirs (16% from 1957-1980). In the Chinese Tien Shan, Urumqihe Glacier lost the equivalent of 4 m ice thickness from 1979-1995[24], and the Chinese Meteorological Administration predicts that China's northwestern mountains will lose over a quarter of their current glacier coverage by 2050. **These glaciers supply 15-20% of the water to over 20 million people in the Xinjiang and Qinghai Provinces alone[45].**

South Pacific

The tropical Carstensz Glaciers in Papua Province (formerly Irian Jaya), Indonesia are melting rapidly; 80% of their collective area was lost between 1942 and 2000[33]. **The West Meren Glacier receded 2600 m since it was first surveyed in 1936, before melting away sometime between 1997 and 1999.** In Papua New Guinea, three summit ice domes that were known to exist in the Central Cordillera Range disappeared in the 1960s[34]. In temperate New Zealand, 127 glaciers surveyed in the Southern Alps have shortened by 38% and lost 25% of their area since the mid 1850s[35]; however, many of these glaciers have advanced in recent decades, presumably due to increased precipitation.

The Meren Valley in the Carstenz Mountains of Indonesia was carved by glaciers, but the last ice melted away completely in the late 1990s.
© WWF-Canon / John RATCLIFFE



Map view of the Mt. Jaya glaciers in Papua Province, New Guinea and changes in their extent since 1936.
© Michael PRENTICE

Glaciers And Freshwater

Although our planet appears to be a watery oasis when viewed from space, most of this liquid is far too salty for humans, plants or animals to consume. Only about 2.5% of the water on earth is freshwater, and less than one-hundredth of one percent is drinkable and renewed each year through precipitation.

Water Shortages

Seventy percent of the world's freshwater is frozen in glaciers, which buffer ecosystems against climate variability by releasing water during dry seasons or years. In tropical areas, glaciers melt year-round, contributing continuously to streamflow and often providing the only source of water for humans and wildlife during dry parts of the year. Freshwater is already a limiting resource for much of the planet, and in the next 30 years population growth is likely to far exceed any potential increases in available water.

The Himalayan glaciers that feed seven of the great rivers of Asia (the Ganga, Indus, Brahmaputra, Salween, Mekong, Yangtze and Huang He) and ensure a **year-round water supply to 2 billion people** are retreating at a startlingly fast rate. In the Ganga, the loss of glacier meltwater would reduce July-September flows by two thirds, causing **water shortages for 500 million people** and 37% of India's irrigated land[8,9]. In the northern Tien Shan mountains of Kazakhstan, more than 90% of the region's water supply is used for agriculture and 75-80% of river runoff is derived from glaciers and permafrost, which are melting at accelerated rates[10]. In the dry Andes, glacial meltwater contributes more to river flow than rainfall, even during the rainy season[11]. Most large cities in Ecuador, Peru and Bolivia rely on meltwater from rapidly disappearing glaciers for their water supply and hydroelectric power, and many communities are already experiencing shortages and conflicts over use[12].

Flooding

Rapid melting of glaciers can lead to flooding of rivers and to the formation of glacial meltwater lakes, which may pose an even more serious threat. Continued melting or calving of ice chunks into lakes can cause catastrophic glacial lake outburst floods. In 1985, such a flood at the Dig Tsho (Langmoche) Lake in Nepal killed several people and destroyed bridges, houses, arable land, and a nearly completed hydropower plant[4]. A recent UNEP study found that 44 glacial lakes in Nepal and Bhutan are in immediate danger of overflowing as a result of climate change[5,6]. In Peru, a chunk of glacier ice fell into Lake Palcacocha in 1941, causing a flood that killed 7000 people; recent satellite photos reveal that another chunk of loose ice is poised over this lake, threatening the lives of 100,000 people below[7].

Flooding caused by runoff from melting glaciers could have disastrous consequences for people living nearby. Source of La Borgne River, Ferpècle Glacier, Valais, Switzerland.
© WWF-Canon / Michèle DÉPRAZ

Sea Level Rise

Average global sea level rose by 1-2 mm per year during the 1900s and is projected to continue rising, with an estimated contribution of 0.2-0.4 mm per year from melting glaciers[2]. The effect of glaciers may be underestimated, however, as recent studies suggest that accelerated melting in Alaska and the Patagonia Icefields since the mid-1990s has increased the combined contribution of just these two areas to 0.375 mm per year[13,14]. **Sea-level rise will affect coastal regions throughout the world, causing flooding, erosion, and saltwater intrusion into aquifers and freshwater habitats.** Even the modest sea-level rise seen during the 20th century led to erosion and the loss of 100 sq km of wetlands per year in the U.S. Mississippi River Delta[15]. In Trinidad and Tobago, as in many low-lying islands, beaches are retreating several meters per year and salinity levels have begun to rise in coastal aquifers[43]. Small Pacific islands such as Tonga, the Marshall Islands and the Federated States of Micronesia are particularly vulnerable, and could lose large portions of their land area to rising seas and storm surges[44]. A global sea level rise of 1 m would inundate 80% of the Maldives, displace 24 million people in Bangladesh, India and Indonesia, and completely eliminate the Sundarbans, the world's largest mangrove forest and home to the endangered Royal Bengal Tiger and hundreds of other species[16].

Bengal tigers face a loss of habitat as glaciers retreat. Their natural habitat in the mangrove forests of the Sundarbans region of Bangladesh and India is being drowned as sea level rises and inundates this area.
© WWF-Canon / Martin HARVEY

Solutions

Worldwide, accelerating glacier loss provides independent and startling evidence that global warming is occurring[1]. It is now clear that the Earth is warming rapidly due to man-made emissions of carbon dioxide and other heat-trapping gases, which blanket the planet and cause temperatures to rise[2]. Climate change is already happening, but we can strive to keep global warming within tolerable limits if we act now.

Based on scenarios of projected damage to ecosystems and human communities, WWF seeks to limit global warming to a maximum of 2ºC over pre-industrial levels. Although a warming of 1-2ºC will clearly threaten human health, water supplies and vulnerable ecosystems, a warming of at least 1ºC appears unavoidable. Warming beyond 2ºC is likely to result in rapidly escalating damages, with severe threats to human populations and the loss of unique and irreplaceable ecosystems. It is therefore imperative that emissions of the main heat-trapping gas, carbon dioxide (CO_2), are significantly reduced, in order to avoid exceeding this 2ºC threshold.

The majority of CO_2 pollution is released when fossil fuels such as coal, oil and natural gas are burned for transportation, heating, or the production of electricity. Coal is particularly damaging, as it produces 70% more CO_2 emissions than natural gas for the same energy output. Electricity generation is the single largest source of man-made CO_2, amounting to 37% of worldwide emissions.

WWF is challenging the electric power sector to become CO_2-free by the middle of this century in industrialized countries, and to make a significant shift towards that goal in developing countries. A number of power companies have already signed on to WWF's vision, but in order to reduce emissions significantly, power utilities, financial institutions, consumers, and policy makers must all play a role:

- Utilities can support meaningful global warming legislation, improve the energy efficiency of power plants, increase their use of renewable energy sources, and halt investment in new coal plants and coal mining.
- Financial institutions can call upon the companies they invest in to disclose their emissions policies, and switch their investments to companies that are striving to be more competitive under future limits on carbon emissions.
- Electricity consumers should opt for "green power" where it is available, demand this choice where it is not, and invest in highly efficient appliances.
- Policy makers must ease the transition to a carbon-free energy industry by passing legislation that creates favorable market conditions, shaping new frameworks for change, and ensuring that the Kyoto Protocol, the world's primary legal tool to combat global warming, enters into force as soon as possible.

Literature Cited

A full list of literature cited in this brochure can be found at **http://www.panda.org/climate/glaciers**

Credits

Text by Stacey Combes, Michael L. Prentice, Lara Hansen and Lynn Rosentrater
Designed by IPMA Worldwide Press

WWF Climate Change Programme

Director: Jennifer Morgan
c/o WWF Germany
Grosse Präsidentenstrasse 10 - 10178 Berlin - Germany
Tel : +49 30 308 742 19
Fax: +49 30 308 742 50
Email: morgan@wwf.de
Website: http://www.panda.org/climate

WWF

WWF's mission is to stop the degradation of the planet's natural environment and to build a future in which humans live in harmony with nature, by:

- conserving the world's biological diversity
- ensuring that the use of renewable natural resources is sustainable
- promoting the reduction of pollution and wasteful consumption