POLICY ANALYSIS

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False Alarm over the Retreat of the Himalayan Glaciers

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EXECUTIVE SUMMARY

Many activists and journalists warn that rapidly melting Himalayan glaciers due to global warming will have catastrophic consequences. The glaciers have been melting since the end of the last ice age 11,700 years ago, but the melting has not worsened recently. Satellite studies suggest that the vast majority of glaciers in the Himalayas are stable, a minority are shrinking, and a few are advancing. The retreat of the Gangotri Glacier, the source of the Ganges River, has decelerated in recent decades to 10 meters (33 feet) per year, at which rate it will last 3,000 years.

Until recently, studies could not distinguish between the contribution of snowmelt and glacial melt to river flows. The one study that does shows that the contribution of glacial melt is less than 1 percent of the river flow in the Ganges Basin and less than 2 percent in the Indus Basin even at high altitudes, and much less downstream. Almost all the river flow is due to rain and snowmelt, both of which will continue even after the glaciers ultimately disappear centuries hence.

Most of India's rain falls during the monsoon season (June to September). Some academics incorrectly claim that in the dry season (February to May) the main Ganges flow comes from glacial melt, so glaciers are critical in this season. In fact, dry season flows come overwhelmingly from snowmelt. Glacial melt occurs mainly when temperatures rise in June to September, coinciding with torrential monsoon rain.

Exaggerations and false alarms about shrinking Himalayan glaciers carry three major risks. First, they subordinate environmental truth to populist fears, misleading public opinion. Second, they increase military tensions between countries sharing Himalayan rivers—China, India, and Pakistan—that already have a history of military conflict. Third, glacier alarmism—some studies claim the Ganges flow will shrink 70 percent as glaciers disappear—can distort agricultural research and planning priorities.


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INTRODUCTION

Several books and journals have recently warned that global warming is going to rapidly melt the thousands of glaciers in the Himalayas that feed major river basins in India, Pakistan, and China—the Ganges, Indus, and Brahmaputra—thus reducing river flows drastically and causing famine. *The Economist* said in a special report on water in 2019 that "about 70 percent of the Ganges flow is contributed by meltwater from the Himalayan glaciers from where the river springs."[1] Victor Mallet, former *Financial Times* correspondent in India, has written a book, *River of Life, River of Death*, in which he says "meltwater from the Himalayas contributes 70 percent of the flow of the Ganges."[2] The Ganges Basin includes the heavily populated states of North India and Bangladesh, home to hundreds of millions of people. Many analysts worry that accelerating melting and the quick disappearance of glaciers will shrink river flows dramatically, devastate agriculture, and immiserate millions. They even fear that premium bottled water that is sourced from glacial melt will worsen the water shortage and ruin the environment.[3]

Several academics and media reports predict that water scarcity will cause wars between nations sharing the rivers that arise in the Himalayas.[4] The latest cause for alarm is China's new proposal to build the world's largest hydroelectric dam—producing three times as much power as its Three Gorges project—on the great canyon of the Yarlung Tsangpo river in Tibet just before it enters India, where it is called the Brahmaputra. Military analysts fear these megadams could be used to divert water to China's water-scarce regions, creating water shortages downstream in India. The megadams could also be used by China to flood India or shrink water flows to a trickle, giving China a powerful new weapon to threaten or punish India without the costs of a military clash.[5]

China thrashed India in a short war in 1962, after which the two sides have managed a tense cease-fire on the border despite constant disputes and intrusions. Diplomatic restraint has succeeded in avoiding firing across the disputed line of control since 1962. But the two countries came very close to a clash over a Chinese intrusion at Doklam in 2019. In May 2020 a Chinese intrusion in the Galwan Valley resulted in hand-to-hand combat that killed 20 Indian soldiers and an unknown number of Chinese. Both sides have built up their forces along their borders and tensions have risen.[6]

Under Xi Jinping, China has become far more assertive on territorial matters, the South China Sea being an outstanding example. It has toughened its stance on India's northeastern state of Arunachal Pradesh, which it claims is South Tibet and therefore is a part of China. Glacier alarmism carries the risk of increasing these tensions as well as increasing public jingoism and the possibility of armed clashes.

> "Many analysts worry that accelerating melting and the quick disappearance of glaciers will shrink river flows dramatically."

India and Pakistan have fought several wars over the disputed Himalayan territory of Kashmir. Different parts of Kashmir are controlled militarily by India, Pakistan, and China. Firing and military clashes across the Indo-Pakistan line of control are common, and the two countries fought a short war in 1999 after a Pakistani intrusion in the Kargil sector of Kashmir. This threatened to escalate into a nuclear conflict before the United States stepped in and persuaded Pakistan to withdraw its troops.[7]

Under the Indus Waters Treaty of 1958, India and Pakistan agreed to share the waters of five rivers flowing from India into the Indus. The treaty gives India use of all the water of the southern three rivers (Sutlej, Ravi, and Beas), while Pakistan gets all the flow from the two northern rivers, the Jhelum and Chenab. These two rivers are crucial for irrigating Pakistan's breadbasket, West Punjab. Both these rivers originate in India. If the Himalayan glaciers disappear and water flows fall dramatically, fresh tensions will arise over the sharing of these river waters. Pakistan has been providing military help to insurgents demanding an independent Kashmir in the Indian-ruled part of the state, and this has already led to demands in India to trash the treaty. Prime Minister Narenda Modi warned in 2016, "Blood and water can't flow together."[8] Pressures to abrogate the treaty will grow if glacial disappearance worsens water flows. Pakistan says any abrogation of the treaty will pose an existential threat to its agriculture. Here again, glacial disappearance could have military consequences.

Former vice president Al Gore has warned that "The Himalayan Glaciers on the Tibetan Plateau have been among the most affected by global warming. The Himalayas contain

100 times as much ice as the Alps and provide more than half of the drinking water for 40 percent of the world's population—through seven Asian river systems that all originate on the same plateau. Within the next half-century, that 40 percent of the world's people may well face a very serious drinking water shortage, unless the world acts boldly and quickly to mitigate global warming."[9]

The good news is that such fears are unwarranted. The Himalayan glaciers have, of course, been melting since the end of the last ice age 11,700 years ago. But melting has not accelerated recently even though temperatures have risen. Satellite monitoring by the Indian Space Research Organization (ISRO) shows, to the surprise of many, that in the decade 2001–2011, the vast majority of glaciers in the Himalayas were stable, not in retreat, and a few were advancing. Alarmists have often raised concerns about the melting of the Gangotri Glacier, the source of the Ganges, which is the holiest of all rivers for Hindus. The glacier is 30 kilometers long (19 miles), the second biggest in the Himalayas. But studies show that, far from accelerating, its retreat has decelerated in recent years to 10 meters (33 feet) per year. At this rate it will last another 3,000 years.[10]

The Himalayas get winter snowfall that covers a huge area many times greater than that covered by glaciers. This snow begins melting in the spring and keeps melting until the glaciers start melting in the summer. Until recently, studies were unable to distinguish between the contribution of snowmelt and glacial melt. The one study employing data to make the distinction finds that the contribution of glacial melt is less than 1 percent of the river flow in the Ganges and less than 2 percent in the Indus even at high altitudes, and much less downstream. Snowmelt contributes many times what glacial melt does to river flows, and rainfall even more. The importance of glacial melt in river flows has been grossly exaggerated.[11]

HISTORICAL REASONS FOR ALARM

One historical reason for widespread alarm is that, in common parlance, the Gangotri Glacier is called the source of the Ganges. Some tributaries of the Ganges also start from glaciers. This gives many people the impression that glaciers, especially the Gangotri Glacier, are critical to the Ganges River flow. Such fears have been stoked, out of ignorance or private agendas, by many activists, journalists, and international organizations worried about climate change. They claim that the melting of glaciers portends the drying up of the huge rivers emanating from the Himalayas—the Ganges, Brahmaputra, and Indus (mostly in Pakistan). They fear desertification of these river basins, exacerbating conflicts over scarce water between countries that already have a history of armed conflict—China, India, and Pakistan.

However, while the Gangotri Glacier may popularly be called the source of the Ganges, it is merely the highest point of the river. It contributes very little to the river's flow. The true source of the Ganges is, in fact, every drop of rain that falls in the Ganges Basin and then flows downhill into the river. The concept of a river basin delineated by watersheds is not well understood by many people. But the fact is that ample rain and snow fall on the huge area of the Ganges Basin, which is 860,000 square kilometers (332,048 square miles). This is many times greater than the relatively small area covered by glaciers.

> "While the Gangotri Glacier may popularly be called the source of the Ganges, it contributes very little to the river's flow."

The Brahmaputra River (called the Tsangpo in its stretch in China) originates and flows for about 1,200 kilometers (746 miles) in Tibet, then makes a U-turn and flows into India, and then flows into Bangladesh. There, it joins the Ganges in a common delta just before entering the Bay of Bengal. Some studies treat the Brahmaputra Basin as separate from the Ganges Basin; others treat the two as a combined Ganges-Brahmaputra Basin. The combined basin is enormous—1.08 million square kilometers (416,990.03 square miles) in area. The Brahmaputra Basin includes the town of Mawsynram in the Indian state of Meghalaya, which holds the world record as the rainiest place in the world, with rainfall averaging 467 inches (1,186 centimeters) per year over the past 38 years.[12] It has overtaken nearby Cherrapunji, an earlier record holder, which today averages 450 inches (1,143 centimeters) per year, but still holds the world records of 364 inches (930 centimeters) of rain in one month (July 1861) and 1,041.8 inches (2,646.17 centimeters) of rain for the 12 months from August 1, 1860, to July 31, 1861.[13] Rainfall in the Ganges Basin is much less torrential but still high by world standards. Dehra Dun at the western end has annual rainfall averaging 86 inches (218 centimeters), while Kolkata (formerly called Calcutta) at the eastern end averages 64.6 inches (164 centimeters). Rainfall can vary sharply between these cities, and droughts can hit some parts of the basin even while some other parts may experience floods in the very same year. The Ganges Basin gets ample rain concentrated in the monsoon months of June to September, especially in its northern parts, where the monsoon clouds encounter the Himalayan foothills, but it gets much less rain in its southern rim.

While acknowledging the completely dominant contribution of the monsoon to flows in the Ganges, some critics point out that the monsoon lasts only three to four months in the summer, followed by a long dry season. The water flow falls to its lowest levels in the three months before the monsoon arrives in June. Some activists and academics argue that in the lean season from February through May, the main Ganges flow comes from glacial melt, and so glaciers are critical during this season, even if not for the whole year. Indeed, the dispute between India and Bangladesh over sharing Ganges waters focuses on providing a minimum flow to Bangladesh in the lean premonsoon season.[14]

> "The notion that glacial flow is critical in the lean season is a myth."

The notion that glacial flow is critical in the lean season is a myth, as explained in a 2009 report of India's Ministry of Environment and Forests by V. K. Raina, former deputy director general of the geological survey of India and one of the authors of this paper. Winter snow at lower altitudes begins to melt in early summer but glacial melt at higher altitudes occurs much later, from the first week of June to mid-September, after which temperatures fall and melting ends. This period of glacial melt coincides almost exactly with the duration of the monsoon, when rainfall dominates flows. Even in the lean season, snowmelt and rain account for almost all flows downstream, and glacial melt contributes very little.[15]

In popular discourse, media reports, or even academic research, very few people distinguish between snowmelt and glacial melt. Yet the distinction is crucial, above all in the lean season, when snowmelt and rain account for virtually all flows. The corollary is that since snow and rain will continue to fall and feed the rivers even after all the glaciers are gone some centuries hence, forecasts of famine and war are much exaggerated, and they lack any scientific basis. Our knowledge of the climate is so uncertain that nobody knows whether climate change decades hence will lead to more or less winter snow and summer rain. But many studies suggest that global warming will mean more evaporation from the oceans, more clouds in the atmosphere, and more precipitation of snow and rain. In that case, the increased contribution of snow and rain to the Ganges flow may conceivably offset the reduced contribution of glacial melt. An International Panel on Climate Change (IPCC) working group issued its fourth assessment report in 2007, in which it estimated that rainfall in the Tibetan plateau would increase 10–30 percent by 2080.[16]

A serious problem for most studies is that the Indian government marks as secret all data on river flows in the Ganges and Indus Basins. This is to avoid fueling the long-standing river disputes India has with Pakistan and Bangladesh, respectively. Given the relatively sour international relations, large numbers of people in Pakistan and Bangladesh believe India is not giving them the water they are supposed to get under the water treaties.

Pakistan has opposed every single dam that India has proposed on two tributaries of the Indus and on the Jhelum and the Chenab. The bilateral Indus Waters Treaty allows India to build run-of-the-river dams that do not impound water in large reservoirs, so there is no diminution of river flow into Pakistan. India has a treaty with Bangladesh providing for some minimal flow of the Ganges into Bangladesh in the lean season. There are no treaties covering some rivers, such as the Teesta (which flows from India into Bangladesh) and the Brahmaputra (which flows from China into India and then into Bangladesh). China does not share river flow data with anybody, even though it is building several dams upstream in Tibet. This lack of river flow data hampers Himalayan studies. This problem has partly been overcome by satellite studies, but satellite data are also official secrets. They are accessible only to those with government permission, and hence, published studies are few in number.

Raina says that in his job he had access to all the confidential data on Ganges and Indus Basin flows. He is not allowed to reveal their detailed contents, but he has been allowed to reveal in public documents (such as his 2009 report) that the Ganges River discharge is overwhelmingly due to rain in the monsoon months of June to September and that the contribution of Himalayan glaciers is small in all seasons, including the lean premonsoon season.

THE INTERNATIONAL PANEL ON CLIMATE CHANGE REPORT OF 2007 PREDICTS GLACIAL APOCALYPSE BY 2035

In 2007, the IPCC published a report stating that "glaciers in the Himalaya are receding faster than in any other part of the world and, if the present rate continues, the likelihood of them disappearing by the year 2035 and perhaps sooner is very high."[17] This created a sensation. Just imagine: Himalayan glaciers, constituting the world's third-largest freshwater body after the Antarctic and Arctic poles (the latter means glaciers in Greenland and other islands in the Arctic Ocean), and hence sometimes called the "third pole," were in danger of disappearing in less than 30 years! However, in the years that followed the report's release, many glaciologists protested that this dire prediction was based not on scientific evidence, but on unwarranted speculation. In an interview with the news agency AFP, Georg Kaser from the University of Innsbruck in Austria, who had headed part of the IPCC's work on the 2007 report, said he had warned in 2006 that the estimate of glaciers disappearing by 2035 was wrong.[18] "It is so wrong that it is not even worth discussing," he told AFP. Yet the IPCC went ahead with the apocalyptic prediction.[19]

The false alarm appears to have originated in a 1999 interview with Indian glaciologist Syed Hasnain of Jawaharlal Nehru University, published in *New Scientist* magazine. His alarming estimate, which he himself called speculative, then resurfaced in a 2005 report by the environmental group World Wildlife Fund (WWF). This was then cited without any confirmation or peer review by the IPCC.

"An alternative genesis lies in the misreading of a 1996 study that gave the date as 2350," wrote BBC environment correspondent Richard Black.[20] It sounds incredible that the IPCC may have predicted apocalypse based on a typo. If so, this was Marx Brothers' stuff parading as true science.

Yet several eminent green journalists and activists rushed to the defense of the IPCC, castigating the critics as climate deniers who rejected science. The then president of the IPCC, R. K. Pachauri, and many of his colleagues defended the apocalyptical prediction as perfectly good science for a long time before being obliged to acknowledge that it was speculation that was unbacked by empirical evidence.

> "When Indian glaciologist Syed Hasnain's predicted glacier apocalypse turned to fiasco, president of the International Panel on Climate Change R. K. Pachauri declared that he had no responsibility for the predictions."

Pachauri was chairman of the IPCC from 2002 until 2015. He was simultaneously also the head of the Energy and Resources Institute (TERI) in India, an important institution that attracted many donors. When the IPCC was awarded the Nobel Prize in 2007, Pachauri claimed this was proof that the IPCC followed the gold standard in scientific excellence, and that its critics were science deniers. In fact, the IPCC won the Nobel Prize for Peace, not for any scientific field.

Pachauri accepted the Nobel Peace Prize in the official award ceremony on behalf of the IPCC, amidst massive cheers and international media coverage. He was able to leverage this media fame to attract international donations for his own outfit, expanding TERI and even spawning a TERI University. He hired Hasnain at TERI to gain the fullest advantage from the man whose work had sparked IPCC's apocalyptic warning. When the apocalypse turned to fiasco, Pachauri declared that he had no responsibility for what Hasnain may have said. And Hasnain said that the IPCC had no business to cite his unrefereed comments.[21]

Additional evidence of IPCC shoddiness came from a different source. Quirin Schiermeier, a regular contributor to *Nature* magazine, revealed that the erring IPCC section "also includes other, smaller errors that are drawing less attention. The chapter attributes to the WWF report, for instance, a related but less drastic estimate that the total area of the Himalayan glaciers could shrink from the present 500,000 square kilometers (193,051 square miles) to 100,000 square kilometers (38,610 square miles) by 2035. The WWF publication gives no such number." He added, "Satellite observations and in situ measurements do suggest that many glaciers are losing mass, but given the observed rate of decline so far, many experts doubt that even small glaciers will melt completely before the end of the 21st century."[22]

> "Ultimately Pachauri and the IPCC had to eat crow and admit they were in error."

In 2008, the Indian environment minister, Jairam Ramesh, appointed Raina to provide an independent estimate of Himalayan melting. It showed there was no acceleration in Himalayan glacial melt in recent years, and thus threatened the basis of IPCC's claim to scientific omniscience and Nobel Prize status. Pachauri told *The Guardian* newspaper, "We have a very clear idea of what is happening. I don't know why the minister is supporting this unsubstantiated research. It is an extremely arrogant statement."[23] He dismissed the Raina report, saying it was not peer reviewed, and even went to the extent of calling it "schoolboy science."[24] Ultimately Pachauri and the IPCC had to eat crow and admit they were in error, which they did in a long-winded apology in 2010: "It has, however, recently come to our attention that a paragraph in the 938-page Working Group II contribution to the underlying assessment refers to poorly substantiated estimates of rate of recession and date for the disappearance of Himalayan glaciers. In drafting the paragraph in question, the clear and well-established standards of evidence, required by the IPCC procedures, were not applied properly. The chair, vice chairs, and co-chairs of the IPCC regret the poor application of well-established IPCC procedures in this instance."[25]

THE RAINA REPORT ON HIMALAYAN GLACIERS

The Indian government appointed Raina to do the study because during his time in office he had done much work on glaciers, notably the Gangotri Glacier. Raina's report was titled *Himalayan Glaciers: A State-of-Art Review of Glacial Studies, Glacial Retreat and Climate Change*.[26] Some of its highlights include a discussion of the formation of glaciers, their rates of melting, and the causes of melting:

- Glaciers are formed by compaction and recrystallization of snow. They move downhill slowly under their own weight. They gain mass overwhelmingly through snowfall, but also through hail, freezing rain, drift snow, avalanche snow, and direct solidification of atmospheric moisture. Every glacier has an accumulation zone (where glacial mass increases since winter snowfall exceeds summer melting), and an ablation (or melting) zone (where mass decreases because summer melt exceeds winter accumulation). These seasonal variations must not be confused with longer term trends.
- The Himalayan glaciers are melting, as they have been doing since the start of the interglacial period after the end of the last ice age. In the 20th century, the average annual retreat was around five meters (16 feet) until the late 1950s, but then it accelerated fast until the late 1980s, reaching up to 30 meters (98 feet) in some years for the Gangotri Glacier, and even more for some smaller glaciers. But glacial retreat decelerated from the 1990s onward, the period when global temperatures have been rising.
- There is no evidence that the rate of melting has accelerated in recent decades, as has occurred in Alaska and Greenland. Glaciers in Alaska and Greenland are at low altitudes, and some even descend to the sea, where temperatures go significantly above the freezing point in summer. By contrast, Himalayan glaciers are at very high altitudes (4,000 meters, or 13,123 feet, on average), where temperatures can fall below the freezing point even in summer, so some glaciers can lose less ice in summer than they gain from winter snow. A topographical theory says that some glaciers at high altitudes may never melt completely.[27]
- Different glaciers are melting at radically different rates. Some are even advancing while others are retreating. The Sonapani Glacier has retreated

500 meters (1,640 feet) in the last 100 years, while the Kangriz Glacier has not retreated at all.[28]

- The biggest glacier by far in the Himalayas is the Siachen Glacier, which is 74 kilometers (46 miles) long. Its snout (terminal point) retreated by just 8–10 meters (26–33 feet) between 1995 and 2008.[29]
- The main causes of glacial melting are very local phenomena, not global warming or other global phenomena. The report describes a particular glacier as having two arms, one of which is retreating even as the other advances. Clearly this represents very local microclimate effects, not global effects. The Kumdam glaciers of the Upper Shyok valley have periodic cycles of surging and retreating. The Siachen Glacier, the biggest in the Himalayas, is over 70 kilometers long (44 miles); it advanced 700 meters (2,297 feet) between 1862 and 1909, retreated 400 meters (1,312 feet) between 1929 and 1958, and then hardly retreated at all in the next 50 years. Such major variations cannot represent a global effect, which would tend to affect all glaciers equally.[30]
- Despite much public concern about the retreat of the Gangotri Glacier, the second-biggest in the Himalayas at 30 kilometers (19 miles) long, its glacial retreat has decelerated, not accelerated, in recent years. Gangotri retreated, on average, 20 meters (66 feet) per year before 2000, but slowed considerably after that, and between September 2007 and June 2009 was practically at a standstill.[31]
- The snout of a glacier is the reference point for judging whether it is retreating or advancing. Even at the snout of Himalayan glaciers, the contribution of snowmelt and glacial melt is no more than 25–30 percent of the total flow in the peak melting month of mid-July to mid-August. Lesser melting takes place in June and September.[32] Glacier thickness also matters. Overall, the Himalayan glaciers are thinning and losing mass.[33]
- Experiments using coal dust suggest that a cover of up to 2 millimeters (0.08 inches) thick on glaciers will tend to absorb more sunshine, reduce reflection, and so quicken glacial melting. But dust thickness of more than 6 millimeters (0.24 inches) acts as an insulator, thus reducing melting.[34] Separate Chinese experiments—these are not mentioned in Raina's study—suggest that covering glaciers with blankets during the summer can reduce melting.
- There are very few Himalayan weather stations, so they provide only partial, intermittent data. Satellites have now provided far more information than was available earlier. However, such data are confidential and accessible only to a few researchers who are given permission.[35]

MORE RECENT STUDIES OF THE GANGOTRI GLACIER

Raina's study gives estimates of the annual retreat of the Gangotri Glacier up to 2007–2009. A subsequent study by Dhruv Sen Singh and others extends the data on retreat until 2015. It also lists estimates given by a variety of researchers over different time periods. Some of these studies estimate retreat for only one year, others for several years.[36]

> "The main causes of glacial melting are very local phenomena, not global warming or other global phenomena."

The data, as shown in Table 1, highlight the fact that the retreat of the glacier has varied markedly over time, showing that very local factors are the key determinants and not global warming. The glacier's retreat was relatively modest at a little over 10 meters (33 feet) per year between 1935 and 1956. After that it accelerated. Different studies suggest different rates of retreat, but one study estimated that it averaged as much as 40 meters (131 feet) per year during 1962–1982. This led to alarmist speculation—such as that voiced by Hasnain—on what might happen if the glacial retreat kept accelerating.

However, the trend then reversed: glacial retreat decelerated. Singh and his coauthors estimate that the glacier's retreat averaged 17.44 meters (57.22 feet) per year during 1976–1990; then it came down to 12.55 meters (41.17 feet) per year during 1990–2001; and then it fell further to 10 meters (33 feet) per year between 2001 and 2015. The irony is that the glacier seems to have accelerated its rate of retreat in the

Table 1

Retreat of the Gangotri Glacier from 1935 to 2015

Time period	Annual snout retreat (meters)	Research reference
1935–1956	10.16	Jangpangi (1958)
1956–1971	27.33	Vohra (1971)
1971–1974	27.34	Puri and Singh (1974)
1974–1975	35.00	Puri (1984)
1975–1976	38.00	Puri (1984)
1976–1977	30.00	Puri (1984)
1977–1990	28.08	Puri (1991)
1990–1996	28.33	Sangear (1997)
1935–1996	18.80	Ravisankar and Srivastava (1999)
1962–1982	40.00	Tangri (2002)
1990	37.00	Tangri (2002)
1999	25.00	Tangri et al. (2004)
2004–2005	12.10	Kumar et al. (2008)
1935–1976	23.95	D. S. Singh et al. (2017)
1976–1990	17.44	D. S. Singh et al. (2017)
1990–2001	12.55	D. S. Singh et al. (2017)
2001–2005	10.14	D. S. Singh et al. (2017)
2005–2012	11.48	D. S. Singh et al. (2017)
2001–2015	10.00	D. S. Singh et al. (2017)

Source: Dhruv Sen Singh et al., "Pattern of Retreat and Related Morphological Zones of Gangotri Glacier, Garhwal Himalaya, India," *Quaternary International* 444, Part A (July 2017): 172–81.

two decades prior to 1982, when global temperatures were not rising and there was speculation about global cooling and the possible coming of a new ice age. But subsequently, when temperatures rose, the rate of glacial retreat slowed down considerably. Given past variations, one cannot confidently predict future trends. But at the latest retreat rate of 10 meters (33 feet) per year, the glacier will last another 3,000 years.[37]

The same study also estimated changes in the ablation zone of the Gangotri Glacier. Every glacier has an accumulation zone where winter snowfall exceeds summer melt, and an ablation zone where melting exceeds snowfall, thus leading to glacial shrinkage and retreat. The area of the ablation zone has gone up and down erratically over the years, but the overall trend has been downward. The area was 21.49 square kilometers (8.29 square miles) in 1990, fell to 17.34 square kilometers (6.69 square miles) in 1993, and then rose to a peak of 22.77 square kilometers (8.79 square miles) in 1995. After that it fluctuated mostly downward. In 2012, the last year covered by the study, the ablation zone was down to 17.04 square kilometers (6.58 square miles), the lowest for any year in the study. This provides additional support to the finding that glacial retreat in recent years has decelerated, not accelerated.[38]

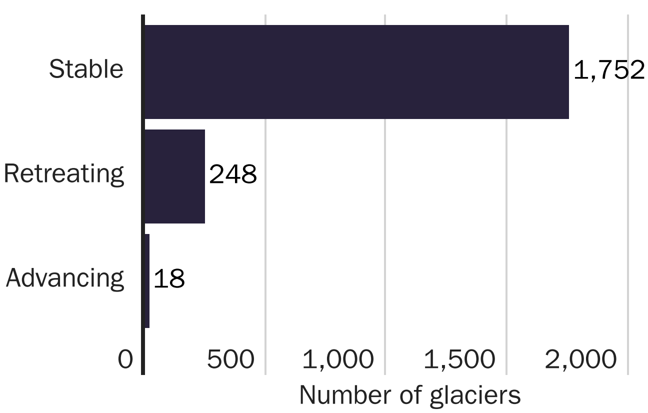
In an all-India online lecture in 2020 that was organized by the government to spread awareness of glacial melting, Singh said, "All glaciers of the Himalaya are retreating at different rates, but at the same time, some are also advancing, which indicates that global warming is not the only reason behind the glacier retreat. However, some extreme climatic events due to global warming have created panic. . . . The Gangotri glacier's pattern of retreat since 1935 shows that it is decreasing, but at the same time, the rate of retreat is continuously declining. Glaciers will melt/retreat whenever temperature is more than zero degree Celsius, but the decreasing rate of retreat is contrary to the panic created over the issue by many organisations."[39]

THE INDIAN SPACE RESEARCH ORGANIZATION'S STUDIES OF HIMALAYAN GLACIERS

The Indian Space Research Organization has been collecting satellite-based data on the Himalayan glaciers for a few decades, which covers the Indus, Ganges, and Brahmaputra Basins. One study between 2004 and 2011 showed that there were 34,919 glaciers spread over 75,779 square kilometers (29,258 square miles) of glaciated area in the entire Himalayan region.[40] Different glaciers have been studied by the ISRO in different periods.

The organization monitored the advance and retreat of 2,018 of these glaciers, representing diverse terrain across the entire Himalayan region, for a full decade from 2000/2001 to 2010/2011. The results have been published in the peer-reviewed journal, *Current Science*. The study monitored 2,018 glaciers that represented diverse terrain across the Himalayan region. Of these, 1,752 glaciers were stable (no change in the snout position and area of ablation zone), 248 were retreating, and 18 were advancing (see Figure 1). All advancing glaciers were in the Karakoram Range, the highest of all. This suggests that altitude is a key factor in the amount of glacial melt. Glaciers at low altitudes face relatively high atmospheric temperatures and so melt faster, while those at high altitudes are colder and melt more slowly, or in some cases, advance. Winter snowfall is much heavier in the Western Himalayas (where the Karakorams are) than in the Eastern Himalayas.

Figure 1
Glacier trends in the Himalayas, 2000–2010



Source: Bahuguna, I. M., B. P. Rathore, Rupal Brahmbhatt, Milap Sharma, Sunil Dhar, S. S. Randhawa, Kireet Kumar, et al. "Are the Himalayan Glaciers Retreating?," *Current Science* 106, no. 7 (2014): 1008–13, http://www.jstor.org/stable/24102387.

- Snowfall feeds the glaciers of the Himalayas. Almost 30–50 percent of the flow at glacier snouts comes from melting runoff. The study gives no separate figures for snowmelt and glacial melt. The contribution of snowmelt and glacial melt progressively reduces as one moves downstream. Rainwater and subsurface water flows contribute more than 70 percent of the flow of the river Ganga at Haridwar, where the Ganges enters the plains.
- Of the 10,250.68 square kilometers (3,957.81 square miles) of total glacial area surveyed by ISRO in this decade, the reduction of glacial area was no more than 20.94 square kilometers (8.08 square miles). This amounts to just 0.2 percent in a decade. At this rate, the glaciers would take 50 years to reduce just 1 percent in area. However, the glaciers are thinning, so glacial mass is decreasing.
- The Indian Space Research Organization mentions that previous studies of earlier decades showed greater rates of glacial retreat and loss of glacial area. But the rate decreased markedly in the decade of 2001–2011. This supports Raina's findings. Monitoring for one decade is insufficient to fully assess the impact of trends like global warming, so longer-term studies may be needed. The ISRO study period overlapped with a pause in global warming between 1998 and 2010, and this could be a factor in explaining the exceptionally high stability of glaciers and low retreat during this period. But there is typically a lag between a change in temperatures and glacial contraction. Longer periods of study will shed more light on the issue.[41]

The ISRO scientists have not published any more studies on the subject since 2014. However, one thing stands out: earlier studies, as well as those of Raina and ISRO, cannot distinguish between the impact of snowmelt and glacial melt. The first research study that had the technology and means to make the distinction was headed by Richard L. Armstrong in 2019. It yielded notable new insights.

THE ARMSTRONG STUDY HIGHLIGHTS THE ROLE OF SNOWMELT

Richard L. Armstrong is a glacial expert at the National Snow and Ice Data Center at the University of Colorado, Boulder, and is credited with several studies of the Himalayas. Along with 12 international collaborators, he published important new findings in a 2019 paper titled "Runoff from Glacier Ice and Seasonal Snow in High Asia: Separating Melt Water Sources in River Flow."[42]

The authors' goal with the paper was to distinguish the specific contribution of seasonal snow apart from that of glacial melt in the major river basins emanating from the Himalayas and adjacent ranges: the Ganges, Brahmaputra, Indus, Amu Darya, and Syr Darya. The authors limited their paper to altitudes above 2,000 meters (6,562 feet), which is extremely high. They did so because flows at low altitudes in the river basins are overwhelmingly from rain, and they wanted to focus on what happened nearer the high glaciers. Since the contribution of snow, ice, and rain vary markedly in different seasons and sections of the Himalayas, the study identified a headwater catchment for each major basin to use for calibration. It then used an innovative new technical methodology to separately calculate the daily melt outputs of snow and glacial ice. This methodology was able to distinguish between flows emanating from four distinct sources: snow on glacier ice, exposed glacier ice, snow on land, and rainfall. The results were remarkable (see Figure 2).[43]

In the Ganges Basin, exposed glacial ice contributed less than 1 percent; snow on ice, 4 percent; snow on land, 43 percent; and rainfall, 52 percent. The combined contribution of snow and ice was as high as 48 percent, but that of glacial ice alone was tiny. Distinguishing between ice and snow torpedoed the notion that glaciers are vital for river flows.[44]

For the Indus Basin, the four contributions were 2 percent, 6 percent, 67 percent, and 23 percent, respectively. The contribution of ice was a bit larger than for the Ganges Basin, but still only 2 percent. The role of snowfall on land was high. This basin has much less rainfall than the Ganges Basin, so the contribution of rain at high altitudes is only 23 percent. Rain's contribution will increase as the river moves downstream out of the high mountains.[45]

For the Brahmaputra Basin, the four contributions were 1 percent, 7 percent, 26 percent, and 66 percent. The contribution of glacial ice is tiny even though the river flows northward from the Himalayas into the high-altitude desert of Tibet, which gets very little rain. The river flows through Tibet's south valley for more than 1,200 kilometers (750 miles) before making a U-turn that pierces the Himalayas and flows into India and then into Bangladesh. After the river enters the Brahmaputra River Valley in India, at much lower altitudes, it encounters some of the rainiest places in the world. But the rainiest spots, Mawsynram and Cherrapunji, lie well below 2,000 meters (6,562 feet), the cut-off altitude for the Armstrong study, and hence are excluded from it. So even the 1 percent contribution of glacial ice is a huge overestimate in downstream areas where the Brahmaputra turns into a truly gigantic river.[46]

The contributions of glacial ice to river flow were 8 percent and 2 percent, respectively, in the high altitudes of the Amu Darya and Syr Darya Basins, which lie mainly in Uzbekistan.[47] Subsequent research by Armstrong gives estimates of the contribution of the four sources for river flows in the entire basins, not just altitudes greater than 2,000 meters (6,562 feet). The figures shrink further for glacial melt. For the Ganges Basin, exposed glacial melt and snow on ice account for less than 1 percent each, snow on land is 5 percent, and rainfall is 94 percent. For the Indus Basin, exposed glacial melt is 1 percent, snow on ice is 5 percent, snow on land is 44 percent, and rainfall is 50 percent. For the Brahmaputra Basin, the contribution of exposed glacial ice is less than 1 percent, snow on ice is 4 percent, snow on land is 30 percent, and rainfall is 65 percent.[48]

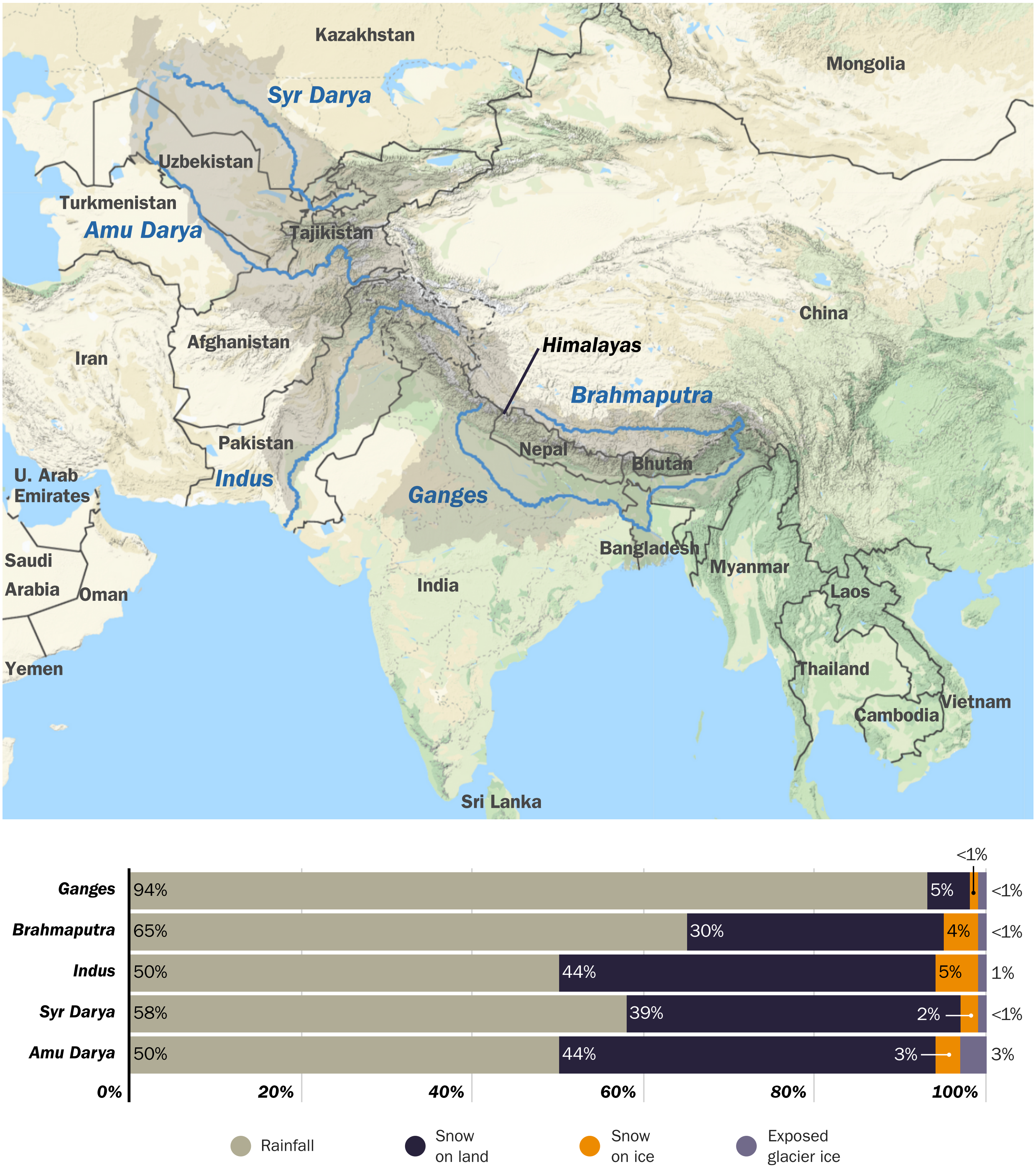
> "In the Ganges Basin, exposed glacial ice contributed less than 1 percent to river flow."

Armstrong notes that other studies show much higher rates of glacial contribution in the Indus Basin, ranging from 18 percent to 40 percent in high altitudes above 2,000 meters (6,562 feet). These higher estimates may actually represent melt from snow on land near the glaciers that is not separated out by other studies. The contribution of snow on land and snow on ice overwhelm ice melt contributions. "The nature of other estimates prevents full separation of snow melt from the ice melt, with some quantity of snow melt implicitly lumped into the ice melt calculation," note Armstrong and his coauthors.[49]

Clearly, earlier studies came to highly exaggerated conclusions about the importance of glacial melt, fueling alarm

Figure 2

Average annual contribution of rainfall, snow on land, snow on ice, and exposed glacier ice to river flow in five rivers of High Asia, 2001–2014 (river basins shaded)



Source: Richard L. Armstrong et al., "Establishing a Collaborative Effort to Assess the Role of Glaciers and Seasonal Snow Cover in the Hydrology of the Mountains of High Asia," the USAID-funded CHARIS project: NSIDC.org/CHARIS, https://cires.colorado.edu/past-fellow-researcher/richard-armstrong.

that the gradual disappearance of glaciers would massively shrink water flows in highly populated basins. We now know better. The glaciers will continue to melt, as they have been doing since the end of the last ice age. At some point centuries hence, almost all Himalayan glaciers, save some at very high altitudes, may melt completely. Even then, the flow of the rivers will hardly be affected, since the contribution of glacial melt is so low.

THE PROBLEM OF GLACIAL LAKES BURSTING

While the melting of glaciers will not lead to dry rivers, they will have other, less dramatic, environmental effects. Melting glaciers carry huge amounts of sediment that can change the course of river channels. When retreating, they dump enormous amounts of rock and debris, called moraines. Moraines can sometimes act as unstable dams that block river flow and create glacial lakes. Some lakes have become large, deep, and potentially dangerous because natural erosion or heavy rainfall can cause a sudden breach that results in serious flash floods as the lakes empty out. These are called glacial lakes outburst floods (GLOFs). Lower-level glaciers are melting and breaking up, creating new glacial lakes. The Himalayas have many thousands of such lakes, of which a significant portion carry dangers.[50]

> "Bhutan's old royal capital, Punakha, has been hit repeatedly by flash floods from bursting glacial lakes."

Millions of glacial lakes were created around the world when the ice sheets retreated after the end of the last ice age, but in many continents such lakes have drained or disappeared long ago. In high northern latitudes—such as Canada, Iceland, and the northern U.S. Rockies—temporary dams can also be formed by glacial ice and icebergs, with or without debris from moraines, and these, too, can cause GLOFs. For instance, in September 2003, a glacial lake lying within the Grasshopper Glacier in Wyoming burst, carved a trench down the center of the glacier for 0.8 kilometers (0.5 miles), and then flooded downstream areas, depositing debris for more than 32 kilometers (19.88 miles).[51] In northern latitudes, such glacial lake bursts tend to occur in remote areas that have little or no population. But the Himalayas are substantially populated, so flash floods kill people and damage farms, villages, and cities. Bhutan's old royal capital, Punakha, has been hit repeatedly by flash floods from bursting glacial lakes in 1957, 1960, 1994, and 2015.[52] Bhutan alone is estimated to have over 2,000 glacial lakes, and the government now has a program to drain the dangerous ones. Nepal has also suffered several GLOFs.[53]

In India, a major Himalayan flash flood in 2013 was caused by exceptionally torrential rainfall that may have been supplemented by the breach of a glacial lake. Another massive flash flood in 2021 was caused by a rockfall and avalanche in the glaciers near Nanda Devi peak. This may have crushed glacial ice below into a wall of water, or perhaps created a temporary dam, allowing water to accumulate and then burst through as a flash flood. Experts are still debating the possibilities. The water raced down the steep mountain course off a tributary of the Ganges, destroying two hydroelectric projects as well as some villages. More than 100 people were killed or went missing.[54]

Switzerland has long dealt with glacial lakes and defused their dangers by either strengthening the banks to prevent breaching or by draining them to safe levels. This requires only simple engineering skills. India, Nepal, and Bhutan have all embarked on programs to reduce GLOFs. Many environmentalists claim that the number and risks of glacial lakes is rising fast because of climate change, but the studies cited in this paper show that glacial melting is decelerating, not accelerating.

SEISMIC AND GEOLOGICAL PROBLEMS SHOULD NOT BE CONFLATED WITH GLACIAL ISSUES

Environmentalists worried about glacial melting have also opposed road building and dam construction in the Himalayas. The two issues should not be conflated. The Himalayas have been created by the constant thrust of the Indian tectonic plate under the Eurasian plate, creating rising, unstable, friable mountains and causing constant seismic shocks that can escalate into giant earthquakes. This makes the construction of roads and dams more problematic than in other parts of the world. Landslides are common throughout the Himalayas and regularly block roads in the monsoon season. Landslides can form temporary dams behind which water builds up and then bursts through as a flood.[55]

The 1950 Assam earthquake measured 8.5 on the Richter scale, and caused almost 5,000 deaths. Massive landslides demolished entire villages. They also temporarily dammed tributaries of the Brahmaputra, creating temporary lakes that later burst and caused major floods that killed more than 500 people.[56] An earlier Assam earthquake, in 1897, measured 8.1 on the Richter scale: it lifted the Shillong plateau by an estimated 11 meters (36 feet), raised the riverbed of the Brahmaputra, and was felt almost 1,600 kilometers (994 miles) away in cities such as Peshawar and Ahmedabad. It was also accompanied by massive floods.[57] The Kashmir quake of 2005 killed an estimated 87,000 people and caused massive flooding. Dozens of lesser quakes have also caused much damage.[58]

> “Himalayan glaciers have been melting and retreating since the end of the last ice age.”

Geological risks in the Himalayas are far greater than glacial ones. The Karakoram Highway was the biggest, most ambitious Sino-Pakistani project ever, connecting the western Chinese provinces of Xinjiang and Tibet with the warm waters of the Pakistan coast, next to the strategic Persian Gulf. The highway was widely hailed as one of the world’s greatest engineering feats, apart from being a major strategic asset that gave China access to the gulf. But in 2010 a landslide blocked the highway and nearby rivers, creating a massive lake 19 kilometers (11.8 miles) long and over 100 meters (328 feet) in depth. This killed and displaced thousands of people. The lake was too big to be drained, so the Karakoram Highway had to be rebuilt along a new route.[59]

Switzerland has safely built hundreds of dams, wide roads, and some of the longest tunnels in the world in the Alps. However, roads and dams in the geologically unstable Himalayas carry more risks than in stabler areas. This must not be conflated with risks caused by climate change or glacial retreat. All Himalayan countries must give serious attention to limiting road width in the fragile Himalayan mountains, and buttressing hillsides to check landslide risks. Dams in this geology require careful design, apart from limits on numbers and locations. However, dams can be built safely to the best international standards, as shown by the Teesta-V hydroelectric project in Sikkim, India. This was reviewed by independent assessors using the Hydropower Sustainability Protocol, an international agreement on best practices. Teesta-V met the protocol’s standards on all 20 performance criteria. The same high standards should be applied to all dams.[60]

POLICY IMPLICATIONS OF GLACIER ALARMISM

This paper combats glacier alarmism and elucidates the truth about glacier retreat. This has several implications for policy. First, the truth itself is important, and environmental policies should be based on scientific truth, not populist fears. Second, glacier alarmism can worsen tensions that already run high between countries sharing Himalayan waters. India and Pakistan have fought several wars in the last 75 years. Indian troops have clashed with Chinese ones in recent years, with a more aggressive geopolitical posture on China’s part. Many strategic thinkers have warned of water scarcity becoming an additional reason for tensions, and maybe a tipping point for military conflict. Glacier alarmism heightens fears of water scarcity and, hence, of conflict. Yet such fears have no scientific basis. A fuller understanding of this, and dissemination of the correct facts to the public, will ease tensions and jingoism in all countries concerned.

Third, glacier alarmism may distort priorities in agricultural research on crop patterns. When distinguished publications such as *The Economist* predict that water flows in the Ganges will fall 70 percent, it may seem logical to switch agriculture and research in North India from high-yielding varieties requiring assured irrigation to drought-prone varieties. In fact, river flows will be virtually unaffected by glacial retreat, so that should not affect cropping patterns or agricultural research priorities.

Fourth, glacier alarmism is unwarrantedly accentuating fears of building dams and roads in the Himalayas, which suffer from serious seismic problems unrelated to climate change or glacial retreat. The Indian tectonic plate keeps thrusting under the Eurasian plate, providing an upward lift to unstable, friable mountains and causing major earthquakes. The design and construction of roads and dams must take these risks into account, but such projects can be completed successfully. With sufficient care, dams can be built that satisfy all performance criteria of the Hydropower Sustainability Protocol.

CONCLUSION

Himalayan glaciers have been melting and retreating since the end of the last ice age, and this has happened around the globe in all interglacial periods. However, the speed and consequences of Himalayan glacial retreat have been grossly exaggerated by the media and environmental activists. Even the IPCC once made the false claim that all Himalayan glaciers might melt by 2035, and then had to retract its statement.

The studies of V. K. Raina, Dhruv Sen Singh, and others have shown that, far from accelerating, the retreat of Himalayan glaciers has been decelerating in recent years even though temperatures have risen. Alarmists who keep issuing warnings of accelerated glacial melting are playing games with the truth. Indeed, in the decade 2001–2011, ISRO monitored 2,018 glaciers, and found that 1,752 glaciers were stable, 248 were retreating, and 18 were advancing.

Until recently, studies could not distinguish between the contribution of snowmelt, glacial melt, and rainfall. The first study to do so shows that, even at high altitudes above 2,000 meters (6,562 feet), glacial melt contributes less than 1 percent of the Ganges' flow, around 1 percent of the Brahmaputra's flow, and 2 percent of the Indus' flow. The contribution of snowmelt is many times higher, since the area covered by winter snow is far greater than that covered by glaciers. As the rivers move downstream the contribution of rain becomes overwhelming.

> "The Indian Meteorological Department has predicted increased rainfall between 2021 and 2040."

Since snow and rain will continue to fall even after most glaciers have melted some centuries hence, the impact of glacial shrinkage on river flows will be tiny. Claims that the rivers will dry up, causing famine and water wars, are very unlikely. Glacial shrinkage and eventual disappearance will have little impact, even in the lean dry season before the summer monsoon; snowmelt dominates in this season, and glacial melt is tiny.

This paper does not address the separate question of the impact of climate change on rainfall. But the Indian Meteorological Department has predicted increased rainfall between 2021 and 2040.[61]

Glacial alarmism can seriously distort policies. It can exacerbate tensions and the risk of military conflict between countries in the region that have major ongoing disputes over the sharing of river waters. It can distort priorities in agricultural research. And, it can exaggerate the risks of building dams and roads in the Himalayas.

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