Himalayan glaciers: The big picture is a montage

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Unusual miscarriages of science (1, 2) recently rocked climate change science and glaciology. An infamous paragraph, uncharacteristic of the rest of the contribution of Working Group II to the Intergovernmental Panel on Climate Change Fourth Assessment, claimed that Himalayan glaciers would disappear by 2035 (1). In such a monumental report, errors can be expected. However, this error, explicated in ref. 3, shredded the reputation of a large and usually rigorous international virtual institution. The gaffe by the Intergovernmental Panel on Climate Change helped to trigger a global political retreat from climate change negotiations, and it may prove to have been one of the more consequential scientific missteps in human history. An equally incorrect claim, on a different timescale, was that large Himalayan glaciers may be responding today to climate shifts 6,000–15,000 y ago (2). However, both mistakes (1, 2) and some solid scientific reporting on Himalayan glacier dynamics (4–10) highlight large gaps in the observational record. In PNAS, Fujita and Nuimura (11) comprehensively reduced the knowledge gap.

Fujita and Nuimura (11) have shown a globally relevant point in reference to the Himalayas. Climate change is heterogeneous, oscillatory, and trending; consequently, glacier responses are heterogeneous, oscillatory, and trending as well.

The measured mass balances of three glaciers in the study by Fujita and Nuimura (11) were between −0.5 and −0.8 m/y water-equivalent thinning. The smallest of the three, AX010 (AX), was thinning by about −0.8 m/y. A simple rule (12) relating glacier volume to area suggests that AX’s present mean thickness is ~24 m; at recent thinning rates, it would indeed disappear in the next few decades, perhaps as soon as 2035. Our rough estimate does not consider the rate of rise of the equilibrium line altitude (ELA; where mass gain by snowfall is balanced exactly by loss caused by melting) calculated by Fujita and Nuimura (11). If this ELA rise rate is maintained, the mass balance will become still more negative, and the glacier will disappear even earlier.

Two other benchmark glaciers are larger and thicker. Fujita and Nuimura (11) found that Yala Glacier (YL) also has a rising ELA, but it may take several decades to ascend above and thus doom the glacier. The larger glacier, Rikha Samba (RS), has a less negative balance, approximately −0.5 m/y, and in 2035, it will be only slightly reduced in area and thickness.

Many larger Himalayan glaciers are also thinning by up to 1 m/y (7–9). With mean thicknesses up to a few hundred meters, the largest glaciers are unlikely to disappear this century, even if thinning accelerates. However, massive glaciers such as Khumbu (Nepal), Gangotri (India), and Siachen (India/Pakistan) will retreat rapidly if supraglacial lakes form and set the glacier on a terminal retreat path.

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The three glaciers analyzed by Fujita and Nuimura (11) have a response time of AX, which may require a couple of decades. The response time of YL is 10 y longer than AX, whereas an adjacent one may have already completed a response. From the areas of the benchmark glaciers (RS > YL > AX) and their precipitation regimes (RS < YL < AX), we suggest that response times should be in a sequence of RS > YL > AX (10). The maxima and minima in the mass balance fluctuations shown by Fujita and Nuimura (11) can be correlated if the response time of RS is 13 y longer and the response time of YL is 10 y longer than the response time of AX, which may have a response time of just a few years. RS, larger and in a drier regime than AX, may require a couple of decades.

The results of Fujita and Nuimura (11) can be linked to the bigger picture of Himalayan glacier changes. India’s Gangotri Glacier (GG), an icon of global climate change (1, 2, 4–6), has a long record of terminus fluctuations (4–6) (Fig. 1). GG has had multicadal terminal retreat rate oscillations since the late 19th century (Fig. 1C). Although we have criticized the work in ref. 2, our satellite data analysis confirms a valid point therein (2): the long retreat of GG has stopped in the last decade. This glacier’s oscillatory retreat provides ample empirical evidence against response times longer than several centuries, which also may be ruled out on a more fundamental physical basis. We suggest a multicadal response to climatic events, such as the Little Ice Age, and dynamical events, such as recent detachments of former tributaries. Thick debris cover, such as the cover of GG, is particularly effective (10) in slowing the glacier retreat rate and
increasing the response time or even halting retreat. However, this finding does not mean that mass loss has ceased, because many debris-laden glaciers are thinning in place without much terminus retreat. For instance, GG, according to our analysis of ASTER digital elevation models from 2001 and 2006 images, may have thinned by about 5 m over that 5-y period despite a seemingly stabilized terminus.

Debris also promotes water retention, and retreat can resume and become rapid after supraglacial lakes form. Stick-slip behavior, in which glaciers can alternately slide over or become immobilized at their beds, can also induce oscillatory retreat and can even interrupt long-term retreat with brief advances. Variability in glacier dynamical responses also relates to the shape of the glacier bed and surface hypsometry (elevation distribution; for instance, whether the ice sits in a deeply eroded high alpine basin, is sliding off a steep cliff, has a long valley glacier tongue, or is an icecap on a plateau). Although it will not disappear anytime soon, GG and probably most other large Himalayan glaciers will likely shrink dramatically this century, with thinning of debris-covered tongues and supraglacial lake growth helping to drive the retreat.

In sum, temporally linear, spatially homogeneous concepts of climate change and glacier response have restricted applicability. Rather, the real world of glaciers and their environment may be likened to a photographic montage in which each montaget element (glacierized subregion or individual glacier) is itself a complex and dynamic picture. Climate change and global glacier impacts have started to clarify and support the public’s common sense that ice melts when it warms. However, it is not a simple picture; scientists must assess each element of the montage and show how it relates to the others. Few details are developed, and the big picture is not yet fully assembled. Fujita and Nuimura (11) have shown the importance of merging synoptic, mountain range-scale observations and models with data for individual glaciers. It is an ongoing scientific mandate to (i) fill in the details, (ii) synthesize the big picture, and (iii) communicate key findings to the public and policy makers. Fujita and Nuimura (11) have added both to the details and the big picture of climate–glacier linkages and other impacts.

The retreat and thinning rates of Himalayan glaciers are similar to those elsewhere. Variability in glacier dynamics, such as shown by Fujita and Nuimura (11), has many causes; the overarching trend is due to global climate change (17), which in recent decades has been driven by both anthropogenic greenhouse gases and natural processes. The science community, from individual researchers to consortia such as GLIMS and the IPCC, must continue to focus simultaneously on the details and the big picture.