LETTER

# Glacier loss on Kilimanjaro is an exceptional case

Thompson et al. (1) present the glacier extent on Kilimanjaro for 2007 and the associated numbers of glacier shrinkage (area and thickness) along with a discussion of the roles of climatological drivers. Because the authors miss vital details of the physical processes acting on Kilimanjaro, they inappropriately propose that "these shrinking ice fields are not unique" (1). We think it is essential to acknowledge these details, because they provide an exceptional opportunity to unravel changes of multiscale linkages in the climate system (sections 6 and 7 in ref. 2).

Regarding glacier shrinkage, usage of relative numbers (1) conceals that absolute rates of area loss have decreased in recent decades (Table 1). Physically, absolute rates of area or volume loss are, however, the most meaningful manifestation of climate forcing (2). Even if outlined conversely by Thompson et al. (1), there is now agreement that slope glaciers are losing mass ($522 \pm 105$ kg $m^{-2}$ $yr^{-1}$) (2). Their long-term trend of area loss, nonetheless, differs from the plateau glaciers (3), so linear extrapolation of total glacier loss (1) leads unsurprisingly to an uncertain prediction (1). Finally, geothermal heat ablates ice in localized areas of the volcano (figure 6 in ref. 4), which requires at least consideration (e.g., ref. 2) when describing disintegration of small glaciers like Furtwängler (1).

For climatological drivers, the atmospheric physics have been established quantitatively to explain that a drier local atmosphere has much stronger effects on Kilimanjaro glaciers than a warmer local atmosphere (ref. 2 and references therein). Assuming that rising local air temperatures in Kilimanjaro's summit zone "are playing an important role" (1) lacks physical basis. Moreover, according to a study cited by Thompson et al. (1; figure 2 in ref. 5), the rise in tropical high-elevation air temperature since the 1970s approaches zero at Kilimanjaro's location. Considering mass fluxes, the undeniable fact that melting occurred in former centuries is based on the observation of "strong and widespread melting" in the 1880s by early scientists (6), and this is consistent with the physically based mass-flux reconstruction for that time (2). Therefore, concluding "the absence of surface melting" on Kilimanjaro before recent decades (1) is invalid.

In summary, there is consensus that glacier loss on Kilimanjaro continues (1–3) and that global warming has probably impacted this loss in recent decades (1, 2), most likely through regional shifts in precipitation zones that result from large-scale warming of air and oceans (ref. 2 and references therein). However, the details above show that Kilimanjaro should not be used as a flagship for contemporary glacier loss for three reasons. (*i*) A rise in local air temperature does not play an important role, because physics teaches us that atmospheric moisture is the principal driver on Kilimanjaro. (*ii*) Glacier shrinkage is not accelerating because absolute rates of total area loss have decreased recently. (*iii*) Melting at present is not unique, because melting was observed in former centuries as well. To lump Kilimanjaro into widespread glacial retreat (1) is, moreover, a waste of an exceptional proxy of climate change.

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**Table 1. Annual rates of area change in different periods calculated from numbers in Thompson et al.'s (1) table 2 (first three columns)**

| Map year | Area ($km^2$) | No. of years | Annual rate of area change per observation period ($km^2$ $yr^{-1}$) |
|---|---|---|---|
| 2007.8 | 1.851 | 1.7 | −0.0465 |
| 2006.1 | 1.930 | 6.0 | −0.0977 |
| 2000.1 | 2.516 | 10.2 | −0.0774 |
| 1989.9 | 3.305 | 13.8 | −0.0628 |
| 1976.1 | 4.171 | 22.5 | −0.1113 |
| 1953.6 | 6.675 | 41.0 | −0.1313 |
| 1912.6 | 12.058 | | |