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Climate change and tropical Andean glaciers: Past, present and future

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Abstract

Observations on glacier extent from Ecuador, Peru and Bolivia give a detailed and unequivocal account of rapid shrinkage of tropical Andean glaciers since the Little Ice Age (LIA). This retreat however, was not continuous but interrupted by several periods of stagnant or even advancing glaciers, most recently around the end of the 20th century. New data from mass balance networks established on over a dozen glaciers allows comparison of the glacier behavior in the inner and outer tropics. It appears that glacier variations are quite coherent throughout the region, despite different sensitivities to climatic forcing such as temperature, precipitation, humidity, etc. In parallel with the glacier retreat, climate in the tropical Andes has changed significantly over the past 50–60 years. Temperature in the Andes has increased by approximately 0.1 °C/decade, with only two of the last 20 years being below the 1961–90 average. Precipitation has slightly increased in the second half of the 20th century in the inner tropics and decreased in the outer tropics. The general pattern of moistening in the inner tropics and drying in the subtropical Andes is dynamically consistent with observed changes in the large-scale circulation, suggesting a strengthening of the tropical atmospheric circulation. Model projections of future climate change in the tropical Andes indicate a continued warming of the tropical troposphere throughout the 21st century, with a temperature increase that is enhanced at higher elevations. By the end of the 21st century, following the SRES A2 emission scenario, the tropical Andes may experience a massive warming on the order of 4.5–5 °C. Predicted changes in precipitation include an increase in precipitation during the wet season and a decrease during the dry season, which would effectively enhance the seasonal hydrological cycle in the tropical Andes.

These observed and predicted changes in climate affect the tropical glacier energy balance through its sensitivity to changes in atmospheric humidity (which governs sublimation), precipitation (whose variability induces a positive feedback on albedo) and cloudiness (which controls the incoming long-wave radiation). In the inner tropics air temperature also significantly influences the energy balance, albeit not through the sensible heat flux, but indirectly through fluctuations in the rain–snow line and hence changes in albedo and net radiation receipts.

Given the projected changes in climate, based on different IPCC scenarios for 2050 and 2080, simulations with a tropical glacier–climate model indicate that glaciers will continue to retreat. Many smaller, low-lying glaciers are already completely out of equilibrium with current climate and will disappear within a few decades. But even in catchments where glaciers do not completely disappear, the change in streamflow seasonality, due to the reduction of the glacial buffer during the dry season, will significantly affect the water availability downstream. In the short-term, as glaciers retreat and lose mass, they add to a temporary increase in runoff to which downstream users will quickly adapt, thereby raising serious sustainability concerns.