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Atmospheric warming at a high-elevation tropical site revealed by englacial temperatures at Illimani, Bolivia (6340 m above sea level, 16°S, 67°W)

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In June 1999, a deep (138.7 m) ice core was extracted from the summit glacier of Illimani, Bolivia (6340 m above sea level, 16°39'S, 67°47'W), and an englacial temperature profile was measured in the borehole. Using on-site and regional meteorological data as well as ice core stratigraphy, past surface temperatures were reconstructed with a heat flow model. The englacial temperature measurements exhibit a profile that is far from a steady state, reflecting an increasing atmospheric temperature over several years and nonstationary climatic conditions. Englacial temperature interpretation,using air temperature data, borehole temperature inversion, and melting rate quantification based on ice core density, shows two warming phases from 1900 to 1960 (+0.5 $\pm$ 0.3 K starting approximately in 1920-1930) and from 1985 to 1999 (+0.6 $\pm$ 0.2 K), corresponding to a mean atmospheric temperature rise of 1.1 $\pm$ 0.2 K over the 20th century. According to various climate change scenarios, the future evolution of englacial temperatures was simulated to estimate when and under what conditions this high-elevation site on the Illimani summit glacier could become temperate in the future. Results show that this glacier might remain cold for more than 90 years in the case of a +2 K rise over the 21st century but could become temperate in the first 20 m depth between 2050 and 2060 if warming reaches +5 K.