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Amplification of high-altitude temperature changes in the American Cordillera driven by precipitation during the Last Glacial Maximum

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Reconstructing the spatial and temporal variabilities of the vertical atmospheric temperature gradient (lapse rate, LR) is key to predict the evolution of glaciers in a changing climate. Variations in this parameter may indeed amplify or mitigate the future warming at high elevation, implying contrasted impacts on the stability of glaciers. Several regional studies suggested that the tropical LR was steeper than today during the last glacial maximum (LGM) (Loomis et al., 2017; Blard et al., 2007), while another study concluded that the LGM lapse rate was similar than today (Tripati et al., 2014).

Here we combine published LGM sea surface temperatures (SSTs) data and LGM moraines dated by cosmogenic nuclides to reconstruct the lapse rate along the American Cordillera. To do so, we combined paleo-Equilibrium Line Altitudes (ELAs) of glaciers with independent precipitation proxies to derive high latitude atmospheric temperatures. The whole dataset includes 34 paleo-glaciated sites along a North-South transect in the American Cordillera, ranging in latitude from 40°N to 36°S. Our reconstruction indicates that the lapse rate (LR) was steeper than today in the tropical American Cordillera (20°N – 11°S). The average ΔLR (LGM – Modern) for this Tropical Andes region (20°N – 11°S) is ~-2 °C.km^{-1} (20 sites). At higher latitude, in both hemispheres, the LR was constant or decreased during the LGM. More precisely, this ΔLR change in the Central Andes (15°S – 35°S) is between 0 and 1°C.km^{-1} (8 sites), while it is ~1 °C.km^{-1} in Sierra Nevada and San Bernardino mountains (40°N – 34°N) (6 sites).

Our results show that a drier climate during the LGM is systematically associated with a steeper LR. Modification of LR during the LGM was already observed from other tropical regions, in Hawaii-Central Pacific (Blard et al 2007), and in Eastern Africa (Loomis et al., 2017). Similarly, in these regions, precipitation did not increase during the LGM. With this multi-site exhaustive synthesis, we make a case that drier Tropical LGM conditions induce a steeper LR. This corresponds to an amplification of cooling at high altitude during the LGM. These results highlight the necessity to consider LR variations in modelling future climate. In a warmer and wetter Earth, temperature increase may be amplified at high elevation, due to smoother LR. If true, this mechanism indicates that tropical glaciers are more threatened by climate change than predicted by current climate modelling.

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