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Declining streamflows reveal nonstationary orographic precipitation enhancement driven by reduced westerly flows

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Although orographic enhancement of precipitation lends mountains an important role in water resources, they are dramatically undersampled by long-term precipitation gages. This has led to the widespread practice of extrapolating trends in low-elevation precipitation gage networks to high elevations via simple climatological precipitation ratios developed from isohyetal maps. An implicit assumption in such a process is non-stationarity in orographic precipitation enhancement, an assumption that can lead to large errors in trend detection and attribution of climate change effects. We show an example from the Northwestern United States where streamflows from mountain watersheds show substantial declines over the last 60 years, even while long-term precipitation gage networks in the region show no trend. We demonstrate that these observed streamflow declines are driven by previously unexplored differential trends in precipitation. November to March westerly winds are strongly correlated with high-elevation precipitation but weakly correlated with low-elevation precipitation. Decreases in winter westerlies across the region from 1950 to 2012 are hypothesized to have reduced orographic precipitation enhancement, yielding differential trends in precipitation across elevations leading to the apparent paradox. Climate projections show continued weakening meridional pressure gradients and westerly flow across the region under greenhouse forcing, highlighting an additional stressor that is relevant for climate change impacts on water resources. This study also reveals the potential of wind speed data from circulation reanalysis products to better inform historical precipitation reconstructions.