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Atmospheric drying limits temperature-growth responses of treeline bristlecone pine

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Tree ring archives from the extremely long-lived bristlecone pine (Pinus longaeva D. K. Bailey) can provide annually-resolved information on historic growth conditions. However, closely located bristlecone pine populations have shown mixed, and sometimes contrasting growth responses to climate variability over the last century. Hence, a better ecophysiological understanding is required to interpret local growth responses in terms of larger scale climate variability. We developed annually resolved chronologies of tree ring width, and cellulose stable carbon (δ13C) and oxygen (δ18O) isotopes from bristlecone pine populations growing near the modern tree line and approximately 200 m below. Combined signals from the carbon and oxygen isotopes were interpreted according to the theoretical principles of the dual-isotope model and a hybrid mechanistic-empirical leaf gas exchange model. Ring widths show positive tree growth anomalies at treeline and consistently slower growth below treeline in relation to 20th century warming and associated atmospheric drying until the 1980s. Growth rates of both populations declined during and after the 1980s when growing season temperature and atmospheric vapour pressure deficit continued to increase. Our model-based interpretations of the cellulose stable isotopes indicate that positive treeline growth anomalies prior to the 1980s were related to increased stomatal conductance and leaf-level transpiration and photosynthesis. Reduced growth since the 1980s occurred with a shift to more conservative leaf gas exchange in both the treeline and below-treeline populations, whereas leaf-level photosynthesis continued to increase in response to rising atmospheric CO_2 concentrations. Our results indicate that warming-induced atmospheric drying confounds positive growth responses of apparent temperature-limited bristlecone pine populations at treeline.