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Reconciling the Antarctic temperature – δ^{18}O relationship on different time- and spatial scales

Content

Water stable isotope ratios (δ^{18}O, δ^{2}H) in polar ice cores are a widely-used proxy for site temperature, yet their calibration has remained challenging. The temperature-δ^{18}O relationship is strongly dependent on the spatial or temporal scale under consideration. In Antarctica, spatial regression of δ^{18}O and surface temperature (T_S) yields a slope of ~0.8 ‰ K^{-1}; temporal regression using the seasonal cycle yields 0.21 to 0.57 ‰ K^{-1}; and the (site-dependent) glacial-interglacial temporal regression slope ranges from 0.8 to 1.45 ‰ K^{-1} in recent estimates. Precipitation isotopes are controlled by the condensation temperature (T_C) that is warmer than T_S owing to the strong near-surface inversion. The T_S - T_C relationship differs on spatial, seasonal, and glacial-interglacial scales, further complicating climatic interpretation of δ^{18}O. A comprehensive description of Antarctic isotopes thus requires a description of the relationship between (at least) six different isotopic slopes (δ^{18}O variations on 3 spatial/temporal scales, each regressed onto T_S and T_C).

First, we will give a short overview of recent estimates of the glacial-interglacial δ^{18}-T_S regression slope based on borehole thermometry and empirical estimates of the gas age-ice age difference (Δage). Next, we combine isotope-enabled simulations using CESM (Community Earth System Model) with an analytical approach called Unified Slope Equations to provide a description of the relationship between the six aforementioned isotopic slopes. We find that the apparent variation in T_S-δ^{18}O slopes mainly reflects differences in the response of the inversion of these time- and spatial scales. Surprisingly, our analysis suggests that the seasonal δ^{18}-T_C regression slope is a good estimate of the glacial-interglacial δ^{18}-T_S regression slope: indeed, at Dome C the former is 1.16 ‰ K^{-1} in published observations (monthly averages, r = 0.9) while the latter is 1.14 ‰ K^{-1} in borehole-based reconstructions. Our framework can reconcile the initially contradictory and disparate isotopic slope estimates found in the literature, and suggests a new observational way to calibrate the ice core isotope paleothermometer.

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Track Classification: Progress in proxy development and interpretation