Decoding Past, Present, and Future Changes in the Large-Scale Circulation with Water Isotopes

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The stable isotope composition of meteoric water is sensitive to multiple competing influences, but often contains a primary signal reflecting local temperature and/or precipitation. Water isotope archives of past climates are thus generally interpreted to reflect changes in these variables over time. However, recent work demonstrates water isotopes house a much richer profile of information, and contain a commingled signal derived from (but not limited to) moisture source & advection, convective history, cloud & rain type, and continental moisture recycling. Given the multivariate climatic influences on water isotope variables, additional observational and modeling constraints may help develop more robust interpretations of both present-day and paleoclimate signals contained in water isotope system observations. Specifically, the use of isotope-enabled GCMs and proxy system models has faciliated attempts to partition individual drivers of changes measured in water isotope records.

This study employs data-model comparison in the water isotope realm to demonstrate that isotope ratios in water vapor & precipitation, while sensitive to local temperature and precipitation amount, can also document robust shifts in atmospheric circulation, moisture convergence & source, and convective mass flux. We employ water isotope-enabled simulations for the Last Glacial Maximum, last millennium, historical period, and 2100. The GCM experiments (generated using iCESM) are evaluated for changes in temperature, the distribution of water vapor, vertical velocity (ω), advection, and water isotopes in vapor (δD_v). Finally, model results are compared to available observations from satellite and paleoclimate data in an attempt to isolate patterns of *circulation change* captured by water isotopes. Specifically, we ask the question, *How much, if any, dynamical information from past climate states can be directly retrieved from water isotope archives*? Circulation impacts on water isotopes in vapor and precipitation are documented for three case studies: (1) the Walker Circulation, (2) the North American Monsoon, and (3) moisture fluxes to the Mississippi river basin. As changes in δD_v with altitude can now be observed by satellites, our results develop metrics for the detection of mean-state changes in large-scale circulation.