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Synthesizing Benthic and Planktonic Proxy Records: State Estimation of the Last Glacial Maximum North Atlantic Circulation

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Paleo ocean circulation is best studied through a synthesis of all available proxy records with known physics. Integration represents a challenge: available data are sparse and irregularly spaced, record distinct views of the ocean state (e.g. seasonality, depth range of the water column, peak versus mean productivity), and carry unique uncertainties (e.g. dating accuracy, analytical precision, calibration uncertainty); ocean circulation models approximate known physics and carry biases and uncertainties; and atmospheric boundary conditions are poorly known. On the other hand, it is conceptually straightforward to formulate the problem as one of statistical estimation with well-known solutions.

Here, state estimation methods are applied to the circulation of the Last Glacial Maximum North Atlantic. Ocean dynamics, as encapsulated in the MIT GCM, are least-squares fit to diverse proxies using an algorithm based on the model adjoint (the Lagrange multiplier methodology). The model uses a domain of 33°S to 75°N at one degree resolution with 23 vertical levels, ICE-5G LGM bathymetry, and an equilibrium seasonal cycle.

A preliminary synthesis exists for benthic δ^{18}O and benthic δ^{13}C records with planktonic records of sea surface temperature (SST). The Marchal and Curry compilations of benthic δ^{18}O and δ^{13}C are used. The state estimate incorporates four MARGO LGM SST reconstructions: foraminiferal assemblages, dinoflagellate cyst assemblages, alkenones, and Mg/Ca. A MARGO-constrained (planktonic data only) state estimate has SSTs that are slightly warmer than modern ones in the sub-tropical gyre and much colder in the sub-polar gyre and in upwelling regions off the west coast of Africa. The horizontal ocean circulation in the sub-tropical and sub-polar gyres is enhanced, while the wind field adjustments produce stronger westerlies and stronger upwelling-favorable winds off the west coast of Africa. Preliminary results incorporating benthic records will be described.