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Interpretation of marine sediment data as an inverse problem

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An inverse method is used in order to evaluate the information contained in sediment data for the Atlantic during the Last Glacial Maximum (near 21 kyr B.P.). The data being considered are an updated compilation of the isotopic ratios ^{18}O/^{16}O (δ^{18}O) and ^{13}C/^{12}C (δ^{13}C) of fossil shells of benthic foraminifera (bottom-dwelling organisms). First, an estimate of the abyssal circulation in the modern Atlantic is obtained, which is consistent with (i) climatologies of temperature and salinity of the World Ocean Circulation Experiment, (ii) observational estimates of volume transport at specific locations, and (iii) the statements of a finite-difference geostrophic model. Second, estimates of water properties (δ^{18}O of equilibrium calcite or $\delta^{18}O_c$ and δ^{13}C of dissolved inorganic carbon or $\delta^{13}C_{DIC}$) derived from sediment data are combined with this circulation estimate in order to determine their consistency with the modern flow. We find that more than about 80% of the water property estimates ($\delta^{18}O_c$ or $\delta^{13}C_{DIC}$) are compatible with the modern flow given their uncertainties. The null hypothesis of a consistency of glacial $\delta^{13}C_{DIC}$ estimates with the modern flow can be rejected at the 5% significance level after two assumptions are made (besides normality): the uncertainty in these estimates, which includes errors in sediment core chronology and in oceanic representativity of benthic δ^{13}C is ± 0.1 permil; and (ii) $\delta^{13}C_{DIC}$ in the glacial deep Atlantic was dominated by a balance between water advection and organic C remineralization. Measurements of δ^{13}C on benthic foraminifera are clearly useful, but the current uncertainties in the distribution and budget of $\delta^{13}C_{DIC}$ in the glacial Atlantic must be reduced in order to increase the power of the test.