# Connecting the circulations of geochemical properties to the circulations of heat and mass: inverse methods for the past and present ocean

GEOFFREY GEBBIE[1]

[1]Dept. Of Physical Oceanography, Woods Hole Oceanographic Institution, Woods Hole, MA, 02543, USA, ggebbie@whoi.edu

There are many ocean circulations: for example, the circulation of various seawater properties and the circulation of mass, which may all be distinct. The connection between the different "circulations" can be made explicit by applying inverse methods developed in the modern-day context to the past. In this talk, we consider the constraints imposed on the Last Glacial Maximum circulations from recent compilations of benthic foraminiferal observations (d13C, d18O, and Cd/Ca) that have nearly 500 points. Even with a numerical model that simply balances tracer fluxes, inverse methods produce self-consistent scenarios including a suite of global 3D tracer distributions, the effect of remineralization, and the pathways of water movement. Large-scale ocean tracer quantities, such as the LGM Atlantic-Pacific difference or the LGM global mean, can be estimated with relatively-small error bars that unambiguously show changes from the modern-day conditions. Geochemical property gradients, however, do not necessarily represent the interface between waters originating from different sources, as is usually assumed in interpreting LGM d13C. Also, minor changes in the circulation of mass may produce large changes in water-mass distributions, provided the circulation is persistent for long time periods. We suggest that progress will be made when rate constraints can be improved.