A Multi-Tracer Data Assimilation Framework for Constraining Global Ocean Transport and Mixing

Nabir Mamnun[1], Tim DeVries[2], Nikita Tournebise[2], François Primeau[3], Heather Graven[1]

[1]Imperial College London, Department of Physics, London, United Kingdom of Great Britain – England, Scotland, Wales
[2]Department of Geography, University of California, Santa Barbara, CA 93106, USA
[3]Department of Earth System Sciences, University of California, Irvine, CA 92697, USA

Abstract

We present a multi-tracer data assimilation framework to constrain global ocean transport and mixing by refining the Ocean Circulation Inverse Model (OCIM) with complementary transient tracer observations. The framework jointly assimilates radiocarbon, chlorofluorocarbons (CFCs), and sulfur hexafluoride (SF6), which together provide sensitivity to ocean ventilation across centennial-to-decadal timescales. It combines a newly compiled global radiocarbon dataset spanning dissolved inorganic carbon measurements and coral and mollusk shell records with quality-controlled CFC and SF6 observations from GLODAPv2. Within a steady-state OCIM configuration, advection and mixing parameters are estimated by minimizing a global tracer-misfit cost function using gradient-based optimization and Bayesian inverse methods. By combining tracers with different temporal sensitivities, the framework is designed to reduce transport–mixing compensation, tighten constraints on large-scale ventilation pathways, and better diagnose diapycnal exchange than single-tracer approaches. The resulting tracer-constrained circulation provides an observationally grounded baseline for studies of ocean heat uptake, carbon storage, and marine biogeochemistry, and offers a practical route for model improvement and parameter estimation in future ocean and coupled Earth-system prediction frameworks.