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Assimilation of Radiocarbon and Chlorofluorocarbon Data to constrain Deep and Bottom Water Transports in the World Ocean

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A global ocean model with time-invariant circulation is fitted to hydrographic and tracer data by means of the adjoint method. Radiocarbon and chlorofluorocarbon (CFC-11 and CFC-12) data are included to constrain deep and bottom water transport rates and spreading pathways, as well as the strength of the global overturning circulation. It is shown that realistic global ocean distributions of hydrographic parameters and tracers can be obtained simultaneously. The model correctly reproduces the deep-ocean radiocarbon field and the concentrations gradients between different basins. The spreading of CFC plumes in the deep and bottom waters is simulated in a realistic way, and the spatial extent as well as the temporal evolution of these plumes agrees well with observations. Radiocarbon and CFC observations place upper bounds on the northward transports of AABW into the Pacific, Atlantic and Indian Ocean. Long-term mean AABW transports larger than 5 Sv through the Vema and Hunter channels in the South Atlantic and net AABW transports across 30˚S into the Indian Ocean larger than 10 Sv are found to be incompatible with CFC data. The rates of equatorward deep and bottom water transports from the North Atlantic and Southern Ocean are of similar magnitude (15.7 Sv at 50˚N and 17.9 Sv at 50˚S). Deep and bottom water formation in the Southern Ocean occurs at multiple sites around the Antarctic Continent and is not confined to the Weddell Sea. A CFC forecast based on the assumption of unchanged abyssal transports shows that by 2030 the entire deep West Atlantic exhibits CFC-11 concentrations larger than 0.1 pmol kg^{-1}, while most of the deep Indian and Pacific Oceans remain CFC-free. By 2020 the predicted CFC concentrations in the DWBC in the North Atlantic exceed surface water concentrations and the vertical CFC gradients start to reverse.