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Effect of ocean mesoscale eddies on global distributions of CFC-11, C-14, and CO2

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Global-scale tracer simulations are typically made at coarse resolution, thus mesoscale eddies are not modeled explicitly. Here we ask what role do eddies play in ocean uptake, storage, and meridional transport of transient tracers. We made transient-tracer simulations in coarse-resolution (2˚ x 2˚, ORCA2) and intermediate-resolution ($^1/_2$˚ x $^1/_2$˚, ORCA05) versions of the global-scale general circulation model OPA9. We focus on the Southern Ocean where air-sea fluxes are largest. For CFC-11, meridional eddy transport, which is largest at intermediate depths, was poleward south of 50˚S and equatorward north of 50˚S. For bomb ^{14}C, meridional transport was poleward throughout the entire Southern Ocean. Although eddy activity was much greater in ORCA05, total meridional transport was nearly identical with ORCA2: changes due to eddy transport were compensated by opposing changes in transport by the mean flow. Eddies had little effect on global and regional bomb-^{14}C uptake and storage. Yet for anthropogenic CO_2 and CFC-11, increased eddy activity reduced Southern Ocean uptake by 25% and inventory by 20% and 30%, respectively. With higher resolution, eddies weaken the “Residual Circulation”, i.e., the sum of Eulerian mean flow and the opposed eddy-induced flow. Eddies reduce the supply of tracer-impoverished deep waters to the surface near the Antarctic divergence, thus reducing the air-sea tracer flux. Both CFC-11 and anthropogenic CO_2 decrease because of rapid air-sea surface equilibration; conversely, the slow air-sea equilibration of bomb C14 gives surface waters little time to exchange with the atmosphere before they are subducted. Additionally, the 30% lower Southern Ocean CFC-11 inventory in the ORCA05 nearly completely remedies ORCA2’s overestimate of the observed inventory. With the standard GM parameterization in ORCA2, there was instead only a 13% reduction.