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Horizontal density compensation in ocean general circulation models

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Density compensation is the condition where temperature (T) and salinity (S) gradients counteract in their effect on density. Open ocean observations with SeaSoar tows and recent glider observations in the Gulf of Mexico reported in the scientific literature suggest that horizontal gradients in the surface mixed layer tend to be strongly density compensated over a range of spatial scales while in seasonal thermocline and deeper layers T,S-fronts are only partially compensated or uncompensated. We assess the capability of ocean general circulation models (OGCM) to develop horizontal density compensation as observed in the upper ocean. The physics required to evolve the initial density compensated mixed layer toward the partially compensated conditions of the thermocline is tested. Idealistic scenarios with horizontal, partially compensated density fronts in the mixed layer are examined in submesoscale-resolved run-down simulations on Hybrid Coordinate Ocean Model (HYCOM). Simulations with no atmospheric forcing show that initial Density compensation does not change substantially experiencing only minor decrease with time simultaneously with the restratification of the mixed layer by submesoscale eddies. Submesoscale fronts tend to be more compensated than mesoscale fronts. A sensitivity analysis shows that the density compensation of submesoscale fronts is particularly sensitive to the horizontal diffusion rate. Simulations with wind forcing exhibit destruction of initial density compensation due to ageostrophic frontogenesis which is confirmed by recent glider observations in the Gulf of Mexico. The lack of the model skill to develop and maintain compensated thermohaline variability is attributed to the T, S horizontal diffusion parameterization used in HYCOM and generally in modern OGCMs: it is decoupled from vertical diffusion and T and S diffusion is horizontally identical. Our findings suggest that OGCM's skill to develop compensated thermohaline variability can be advanced by providing realistic atmospheric forcing along with improving horizontal diffusion parameterization.