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Assessing ocean mixing under heterogeneous sea ice cover in climate models

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Heterogeneous ice pack with sporadic narrow but long leads in the polar oceans was unresolved in typical climate model grid. Although multi-category sea ice thickness distribution was used in one sea ice model grid to calculate separate heat, salt and tracer fluxes through each category, the ocean models use only single-column grid to communicate with the averaged fluxes from all categories. Previous studies have demonstrated some improvements of the ocean mixing and sea ice thermodynamics using a parameterization scheme in winter in a 3-D ice-ocean model and vertically 1-D multi-column ocean grid (MCOG) in summer. Due to lack of direct observational data to validate the model improvements, these schemes have not been adopted in most climate models. The study used a series of idealized ocean model experiments to quantify ocean mixing errors when the lead with high brine rejection was unresolved by model grid. When lead is resolved, the rejected brine during ice formation will sink to the base of the mixed-layer and spread horizontally. The model errors were found to be systematic and increasing with time when the lead is unsolved and the brine was spread into one much larger model grid cell: saltier surface, fresher at the base of the mixed-layer and deeper mixed layer depth. The mixing by an average wind of 5.5m/s will not change the vertical distribution of the rejected brine. The existing parameterization scheme was evaluated and found to be beneficial under certain conditions. A new scheme with the n power parameter linked to lead concentration was best fitted from idealized model results with different lead concentrations in one grid cell. The new scheme produced more accurate results and consistent over time for the full range of sea ice concentrations from near zero to 100%. The MCOG scheme can greatly improve the accuracy of the ice-ocean fluxes, but it also notably increases computational costs and requires big changes of the existing ocean model structure. The columns in MCOG can be averaged every time step to reduce computational cost, but a horizontal salt spread among columns at the base of mixed-layer needs to be parameterized to produce the correct results.