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Added and redistributed heat and carbon in climate model projections for the Southern Ocean

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Projected changes in ocean heat and carbon storage are assessed in terms of the added and redistributed tracer using a transport-based framework for 6 CMIP5 Earth system models following an annual 1% rise in atmospheric CO_2 . Heat and carbon budgets for the added and redistributed tracer are used to compare the reasons for the relatively-reduced storage of heat and carbon within the Southern Ocean. Here the added tracer takes account of the net tracer source and the advection of the added tracer, while the redistributed tracer takes account of the time-varying advection of the pre-industrial tracer distribution. The added heat and carbon are nearly always positive over the Southern Ocean with the net source acting to supply tracer. However, there is a relatively-reduced local storage of heat and carbon in the Southern Ocean due to the passive northward transport of heat and carbon by the overturning, which is augmented by a passive northward carbon transport for the gyre circulation. In contrast, the redistributed heat is usually negative and the redistributed carbon is positive over the Southern Ocean due to the transport effects of a strengthening residual circulation and the opposing gradients in the pre-industrial temperature and CO_2 . Hence, climate projections for the Southern Ocean are expected to have heat anomalies of a variable sign and carbon anomalies of a consistently positive sign, since the effects of added and redistribution heat are opposing in sign, while the effects of added and redistributed CO_2 reinforce each other.