Using large ensembles to elucidate the possible roles of Southern Ocean meridional overturning circulation in the Southern Ocean SST trend

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Abstract

One of the most puzzling observed features of recent climate has been a multidecadal surface cooling trend over the Southern Ocean (SO). We use large ensembles of simulations to study the role of the SO meridional overturning circulation (MOC) in these sea surface temperature (SST) trends. We find that multiple competing processes play prominent roles, consistent with multiple mechanisms proposed in the literature for the observed cooling. Early in the simulations (20th century and early 21st century) internal variability of the MOC can have a large impact, in part due to substantial simulated multidecadal variability of the MOC. Ensemble members with initially strong convection (and related surface warming due to convective mixing of subsurface warmth to the surface) tend to subsequently cool at the surface as convection associated with internal variability weakens, leading to surface cooling. A second process occurs in the late 20th and 21st centuries, as weakening of oceanic convection associated with global warming and high latitude freshening can contribute to the surface cooling trend by suppressing convection and associated vertical mixing of subsurface heat. As the simulations progress the multidecadal SO variability is suppressed due to forced changes in the mean state and increased oceanic stratification. As a third process, the shallower mixed layers can then rapidly warm due to increasing forcing from greenhouse gas warming. Thus, different processes could conceivably have led to the observed cooling trend, consistent with the range of possibilities presented in the literature.

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