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Subpolar Southern Ocean response to changes in the surface momentum, heat and freshwater fluxes under 2xCO2

Fabio Boeira Dias[1], Catia Domingues[2,3], Simon Marsland[2,3,4], Stephen Rintoul[5,6,7], Petteri Uotila[1], Russ Fiedler[5], Mauricio Mata[8], and Abhishek Savita[2,3,4]

[1]University of Finland, Institute for atmospheric and Earth system research, Helsinki, Finland (fabio.boeiradias@helsinki.fi)
[2]Institute for Marine and Antarctic Studies, University of Tasmania, Hobart, Tasmania, Australia
[3]ARC Centre of Excellence for Climate Extremes, University of Tasmania, Hobart, Tasmania, Australia
[4]CSIRO Oceans and Atmosphere, Aspendale, Victoria, Australia ARC
[5]CSIRO Oceans and Atmosphere, Hobart, Tasmania, Australia
[6]Centre for Southern Hemisphere Oceans Research, Hobart, Tasmania, Australia
[7]Australian Antarctic Program Partnership, Hobart, Tasmania, Australia
[8]Instituto de Oceanografia, Universidade Federal do Rio Grande, Rio Grande, RS, Brazil

- The subpolar Southern Ocean (sSO) around Antarctica has fundamental climate importance. The densest water mass in the global ocean, Antarctica Bottom Water (AABW), originates in the sSO and supplies the lower limb of the Meridional Overturning Circulation (MOC), occupying about 36% of the ocean's volume. However, climate models struggle to represent the processes involved in formation of AABW on the continental shelf, resulting in large differences between models and observations and a wide spread in projections of sea level and other properties. We explore the source of these persistent model biases by examining the response of the sSO to perturbations in surface forcing. Using an ocean-sea ice model (ACCESS-OM2) that forms AABW both on the shelf and in open-ocean (similar to other coarse resolution models), we investigate the sSO response to individual and combined perturbations of surface heat, freshwater and momentum fluxes following the FAFMIP-protocol. The wind perturbation (i.e. a poleward shift and intensification of the Southern Ocean Westerlies) has the dominant effect, enhancing AABW formation and accelerating the MOC. This occurs through upwelling of warm waters and inhibition of sea-ice growth during winter, which triggers large open-ocean polynya events with associated deep convection. These events occur in the Weddell and Ross Seas and their variability is associated with the heat available at mid-depth; open-ocean polynyas cease when the heat reservoir is depleted. The effects of surface warming and freshening only partially compensate the changes due to wind by increasing the ocean stratification and reducing AABW formation. These results are relevant for the interpretation of climate change projections, suggesting that other coarse models might respond in similar way and present an opposite trend than those seen from observations.