EGU21-3016, updated on 19 May 2021
https://doi.org/10.5194/egusphere-egu21-3016
EGU General Assembly 2021
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The sensitivity of Southeast Pacific heat content to changes in ocean structure

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The Southern Ocean features ventilation pathways that transport surface waters into the subsurface thermocline on timescales from decades to centuries, sequestering anomalies of heat and carbon away from the atmosphere and thereby regulating the rate of surface warming. Despite its importance for climate sensitivity, the factors that control the distribution of heat along these pathways are not well understood. In this study, we use an observationally-constrained, physically-consistent global ocean state estimate (i.e. ECCOv4) to examine how changes in ocean properties can affect the heat content both in the mixed layer and in the recently ventilated subsurface, focusing on the Southeast Pacific. First, we carry out a comprehensive adjoint sensitivity study using near-surface heat content as the objective function, highlighting the locations and timescales with the largest potential to affect the properties of relevant subduction regions. Next, we use a set of numerical tracer release experiments to identify the subduction and export pathways from the surface into the subsurface thermocline, thereby defining the recently ventilated interior. Using the tracer distribution to define our objective function, we employ an adjoint method to calculate temporally-evolving sensitivity maps that highlight the processes, locations, and timescales that are potentially most relevant for changing the heat content of the recently ventilated Pacific. In order to examine the full nonlinear response, we use the adjoint sensitivity fields to design a set of forward, nonlinear perturbation experiments. We find surprisingly weak sensitivities to high latitude wind stress and heat flux, and relatively high sensitivities to wind stress curl in subpolar latitudes. Despite the localized nature of mode water subduction hotspots, changes in basin-scale density gradients are an important controlling factor on heat distribution in the Southeast Pacific.