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Transient response of surface-forced water mass transformation over the Southern Ocean and its connection to overturning and ventilation

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The water mass transformation (WMT) framework provides a useful perspective on interior ocean circulation because it combines the influence of surface forcing and diapycnal mixing with overturning. Observational analyses, as well as the majority of ocean model diagnostics, only adequately resolve surface-forced transformation of water masses and rely on inference or rough approximations to quantify the effect of the interior transformation term due to mixing. Here we characterize the connection between surface-forced WMT and meridional overturning of the Southern Ocean in two state-of-the-art GFDL coupled climate models. We assess the mean state of the system as well as the transient response to changes in surface forcing. For the latter, we analyze a set of idealized perturbation experiments in which changes in Antarctic ice sheet melting and Southern Ocean wind stress are imposed. Assessment of the mean state in the two climate models is consistent with previous studies that identified overturning as a balance between surface and interior WMT, with the surface component being the dominant term. However, the perturbation runs in both models demonstrate important differences in the response of surface WMT and meridional overturning. Changes in overturning are consistent with surface WMT but are muted in terms of intensity, location, and the density at which they occur. This points to a crucial role for interior WMT associated with mixing, as well as changes in water mass volumes, which are important terms in characterizing anticipated shifts in overturning and ventilation in the Southern Ocean in response to anthropogenic forcing.