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Antarctic physics of the glacial carbon cycle.

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Understanding why the deep ocean sequesters large amounts of CO_2 during cold climate periods is one of the most relevant questions of paleoclimate today. One prominent explanation is that the Southern Ocean (SO) was more stratified during glacial times, leading to reduced contact of deep CO_2-charged water with the surface. Here, the proposed mechanisms for stratification of the SO and several important modifying processes are examined in a comparative mode, first in isolation to quantify their individual importance and then in combination to understand their interactions. Among possible drivers of polar stratification during cold climates are an equatorward shift of the southern hemisphere westerly winds and the effect of global cooling through the non-linearity of the equation of state (EOS). Additional factors that require consideration in the context of those mechanisms include a reduction of the strength of the hydrological cycle as a result of atmospheric cooling and the effect of a global increase in ocean salinity (again through the EOS). The experiments were performed using the GFDL MOM4 ocean general circulation model with simplified basin geometry and bathymetry, coupled to an sea-ice model and an energy moisture balance model for the atmosphere.

To illustrate how we isolated the competing mechanisms, consider the effect of global cooling on SO stratification. At low temperatures, the sensitivity of ocean density to temperature variations is greatly reduced because of the non-linearity of the EOS. It follows that the freshwater-stabilized polar waters should be more resistant to cooling-induced overturning during globally cold climatic periods. To test the plausibility of this effect alone, without invoking other contributing factors, we have reduced the temperature of the entire model ocean by a fixed amount, but only in the calculation

of the density.

Overall we found that the effect of the colder global temperatures and an equatorward wind shift both play a first order role in stratifying the SO. The reduced hydrological cycle is an important counter factor while the effect of a global increase in salinity is minimal.