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Geoengineering Outlet Glaciers and Ice Streams

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Mass loss from Greenland and Antarctica is highly sensitive to the presence of warm ocean water that drives melting of ice shelves and marine terminated glaciers. This warm water resides offshore at depth and accesses the grounding line through deep but narrow troughs and fjords. Here, we investigate the possibility of blocking warm water transport through these choke points with an artificial sill. Using a simple width-averaged model of ice stream flow coupled to a buoyant-plume model of submarine melt, we find that grounding line retreat and sea level rise can be delayed or reversed for hundreds of years if warm water is prevented from accessing outlet glaciers and ice-shelf cavities. Glaciers with a floating shelf exhibit a strong response to the presence of the artificial sill regardless of our choice of calving law, while tidewater glaciers require a strong linkage between submarine melt and iceberg calving for the artificial sill to have an effect. As a result of this difference and as a result of differing degrees of overdeepening in the basal topography, Antarctica and Greenland present very different societal cost-benefit analyses. Intervention in Greenland would be low-cost and low-reward: the volume of the artificial sill is comparable to existing large public works projects such as the Dubai Islands or the Suez Canal, but the magnitude of averted sea-level rise is small, the success of the intervention depends on the choice of calving law, and the glaciers return to their non-geoengineered trajectories within one to two centuries. Intervention in Antarctica, on the other hand, would be high-cost and high-reward: the volume of the artificial sill is one to two orders of magnitude greater, but the averted sea level rise is much larger, the intervention is successful regardless of the choice of calving law, and the ice streams remain far from their non-geoengineered trajectories throughout the 1000 year duration of our model runs. In both cases, an artificial sill cannot save the glaciers forever if the climate continues to warm and surface melt continues to increase, but glacial geoengineering may offer society a way to delay irreversible grounding line retreat and thus buy time while emissions reduction and carbon removal efforts are underway.