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The ECCO Consortium: Adjoint sensitivities of sub-ice shelf melt rates to ocean circulation under Pine Island Glacier, Antarctica.

Patrick Heimbach[†];
[†] MIT, USA
Leading author: heimbach@mit.edu

Melt rates underneath floating ice shelves are difficult to observe directly. Estimates of melt rates rely mostly on indirect methods and are subject to large uncertainties. These uncertainties are a serious gap in the connection between observed oceanic changes and ice shelf thinning. The present study is a first step toward addressing this issue in the context of inverse modeling. We address the problem to which extent ocean hydrographic observations away from the ice-ocean boundary can, by themselves, be used to constrain sub-ice shelf melt rates. To this end, we derive comprehensive sensitivity patterns of sub-ice shelf melt rates to changes in ocean circulation. Our study region is the Pine Island Ice-Shelf, a well-contained region in the Amundsen Sea Embayment, and well-suited for this feasibility study. The sensitivity patterns are computed with an adjoint model of the MITgcm, a full-fledged ocean general circulation model that resolves the sub-ice shelf circulation and includes a thermodynamic melt rate parameterization. Simulations presented span a range from coarse-resolution (1/8 degree) configurations such as used in global-scale simulations, to detailed high-resolution (1/32 degree) configurations suitable for regional studies. The adjoint state can be used to identify dominant water mass pathways and time scales that affect melt rates, provide guidance for oceanographic field campaigns for deploying limited measurement assets in an optimal manner, and establish the feasibility of connecting hydrographic observations to constrain melt rates in formal estimation approaches such as those undertaken within the Estimating the Circulation and Climate of the Ocean (ECCO) consortium.